Sediment TMDL Development for the Coleman Creek Watershed Located in Halifax County, Virginia

Submitted to:

Virginia Department of Environmental Quality

Prepared by:

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EXECUTIVE SUMMARY

This sediment Total Maximum Daily Load (TMDL) study is for Coleman Creek (Table E.1), which is designated as impaired because it does not meet Virginia's water quality standards for aquatic life (benthic) use. Based on stressor analysis, streambed sedimentation was identified as the most probable stressor of the benthic impairment.

Table E.1. Summary of Impairment.

TMDL Watershed	Impaired Segment	305b Segment ID	Year First Listed
Coleman Creek	Coleman Creek	VAC-L74R_CLB01A06	2008

Description of Study Area

Coleman Creek is a headwater stream in the Piedmont geographic province in Halifax County, Virginia and is a tributary of the Hyco River (Figure E.1). It is approximately 7 miles south of the Town of South Boston. It is part of the Lower Dan River Watershed that is in the Roanoke River Basin.

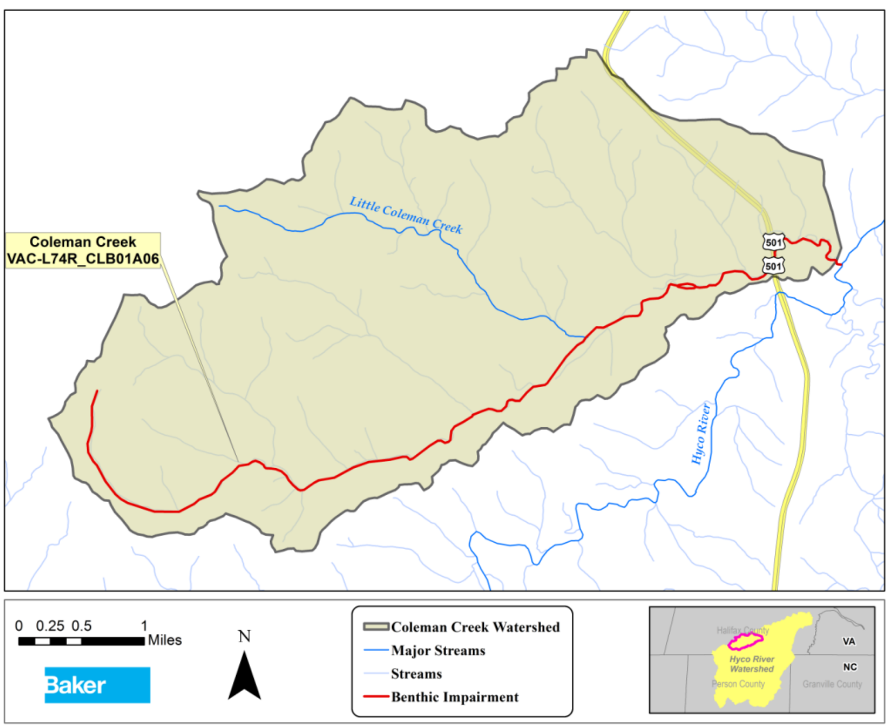

Figure E.1. Coleman Creek Watershed.

Impairment Description

Coleman Creek was determined to be impaired in 2008 based on assessments of biological monitoring data and using the Virginia Stream Condition Index (VSCI) methodology. Coleman Creek is included in the EPA Category 5 list which means that it requires a TMDL.

Applicable Water Quality Standards

Coleman Creek was determined to violate Virginia's General Standard (9 VAC 25-260-20) based on assessments at biological station 4ACLB001.90 at Coleman Creek of the in-stream benthic macroinvertebrate community. This means that Coleman Creek does not fully support the aquatic life designated use for Virginia's waters (9 VA 25-260-10).

According to Virginia Water Quality Standards (9 VAC 25-260-10): *"all state waters are designated for the following uses: recreational uses (e.g., swimming and boating); the propagation and growth of a balanced indigenous population of aquatic life, including game fish, which might be reasonably expected to inhabit them; wildlife; and the production of edible and marketable natural resources (e.g., fish and shellfish)."*

Virginia's General Standard (9 VAC 25-260-20) states that *"All state waters, including wetlands, shall be free from substances attributable to sewage, industrial waste, or other waste in concentrations, amounts, or combinations which contravene established standards or interfere directly or indirectly with designated uses of such water or which are inimical or harmful to human, animal, plant, or aquatic life."*

Watershed Characterization

The Coleman Creek watershed is 8,626 acres in size. It is located entirely within the Northern Inner Piedmont (45e) sub-division of the Piedmont (45) ecoregion. Ecoregion 45e is dissected upland composed of hills, irregular plains, and isolated ridges and mountains. Average annual precipitation is 44.9 inches and the average annual daily temperature is 56.7°F. Topography is characterized with low, rolling hills ranging in elevation from 320 feet to 500 feet above sea level. Soils are predominantly sandy loam to clay loam types with moderate- to well-drained characteristics. Forest comprises 64 percent of the watershed, followed by 30 percent pasture and hay, five percent developed and urban green space, and less than one percent cropland.

Assessment of the biological data at monitoring station 4ACLB001.90 along Coleman Creek shows that the VSCI is lower than the VADEQ's optimal VSCI threshold which is 60. VSCI is used to assess the aquatic life use status of wadeable freshwater streams and rivers in non-coastal areas of the state. VSCI values less than the optimal threshold are determined to be impaired.

Stressor Analysis

A stressor analysis was conducted to determine the most probable stressor that is causing the benthic impairment in Coleman Creek. Several candidate stressors were evaluated including ammonia, pH, temperature, metals, toxic organic compounds, nutrients, organic matter, streambed sedimentation, and ionic strength.

Based on the stressor analysis, streambed sedimentation was selected as the most probable stressor causing the benthic impairment of Coleman Creek.

Reference Watershed Approach

Since there are no in-stream water quality criteria for sediment in Virginia, the reference watershed approach was used to establish a TMDL endpoint that would represent the non-impaired condition.

Winn Creek watershed was selected as the reference watershed based on its similarity to Coleman Creek watershed in terms of land use, topography, ecology, and soils characteristics with those of the impaired watershed. Based on two biological assessments conducted in spring and fall of 2010, Winn Creek was evaluated to be fully supporting its benthic macroinvetebrate community with VSCI scores of 68.6 and 70.6, respectively. Winn Creek watershed also lies completely within Halifax County and is approximately 12 miles north of Coleman Creek watershed.

TMDL Technical Approach

The Generalized Watershed Loading Function model (GWLF) was selected because it has become the model of choice for developing sediment TMDLs in Virginia using the reference watershed approach.

Models of both Coleman Creek and Winn Creek watersheds were created to estimate the existing annual sediment loads. In the absence of observed flow data in Coleman Creek, the Coleman Creek GWLF model was calibrated based on the simulated flows from the Hyco River HSPF model for the period from January 2005 to December 2012. The Hyco River HSPF model was developed to support the development of bacteria TMDLs for the Hyco River watershed which includes the Coleman Creek watershed. When using the reference watershed approach, the hydrologically calibrated model is considered adequate to establish the TMDL endpoint and to estimate the required sediment load reductions in the impaired watershed relative to the TMDL endpoint without performing a water quality calibration. The TMDL was derived by simulating existing loads from both Coleman Creek and Winn Creek watersheds for the period from January 2000 to December 2012.

TMDL Calculations

The TMDL represents the maximum amount of a pollutant that the stream can contain without exceeding the water quality standard. The load allocation for the selected scenarios was calculated using the following equation:

$$TMDL = \Sigma\ WLA + \Sigma\ LA + MOS$$

Where,

WLA = waste load allocation (point source contributions and future growth);
LA = load allocation (non-point source contribution); and
MOS = margin of safety.

Table E.2 shows the summary of existing annual average sediment loads from the Coleman Creek and Winn Creek watersheds. Following the reference watershed approach, the TMDL endpoint was established as equal to the estimated loads from the Winn Creek watershed. Table E.2 shows that the existing average annual load from the Coleman Creek watershed is higher than the TMDL endpoint.

The sediment load from Coleman Creek watershed will have to be reduced to a level that takes into account the future growth WLA and MOS.

Table E.2. Estimated Annual Average Sediment Loads from Coleman Creek and Winn Creek Watersheds.

Land Use/Source Categories	Sediment Loads (metric tons/year)	
	Coleman Creek	Winn Creek*
Forest	128.9	68.4
Harvested Forest	47.7	23.3
Pasture	816.6	745.2
Riparian Pasture	149.7	28.5
Hay	26.0	68.9
Crop	17.8	61.1
Developed	63.8	62.7
Transitional (Barren)	17.0	0.0
Channel Erosion	107.9	56.0
Total	**1375.3**	**1114.1**
*Note – Area adjusted reference watershed.		

Table E.3 shows the TMDL expression for the Coleman Creek watershed. An explicit 10% MOS was used equivalent to 111.4 metric tons/year. There are no permitted wastewater facilities or active land disturbing (construction stormwater) activities in the Coleman Creek watershed. The watershed is also primarily rural and is not expected to experience any significant development in the future. Halifax County population also declined based on latest Census survey. However, as per VADEQ guidance, Future Growth WLA is set to two percent of the TMDL to allow future permitted construction and development activities beyond what is currently observed in the watershed. This corresponds to a value of 22.3 metric tons/year of sediment load allocated for future growth. The load allocation for nonpoint sources was calculated as the difference between the TMDL, and the sum of WLA and MOS. This value is equal to 980.5 metric tons/year.

Table E.3. TMDL Expression for the Coleman Creek Watershed (metric tons/year).

TMDL (metric tons/year)	WLA (metric tons/year)	LA (metric tons/year)	MOS (metric tons/year)
1114.1	22.3* *Future Growth WLA	980.5	111.4

Table E.4 shows that the percent reduction required in nonpoint sources to meet the LA as per the TMDL is 28.7 percent which is equivalent to a 395.1 metric tons/year reduction. Table E.5 shows three alternative allocation scenarios that will meet the overall load reduction required. Each allocation scenario recommends a target load reduction for each source category. Scenario 1 assumes an equal percent of target load reduction for all source categories except forest. With harvested forest as a separate source category, no target reductions are assigned for forest for any of the three scenarios. Scenario 2 represents the situation where source categories such as pasture/hay/riparian pasture, harvested forest, and channel erosion that have significantly higher load contribution per unit area are specifically targeted for reduction. Scenario 3 represents the scenario where the overall required load reduction is achieved through targeted reductions from all nonpoint sources in the watershed (i.e., not including channel erosion). The final allocation scenario for implementation will be selected during the TMDL implementation planning.

Table E.4. Required Load Reduction and Percent Reduction for Coleman Creek Watershed to Meet TMDL.

Existing NPS loads (metric tons/year)	1,375.5
Load Allocation (LA) (metric tons/year)	980.5
Load Reduction Required (metric tons/year)	395.1
Percent Load Reduction Required	28.7

Table E.5. TMDL Allocation Scenarios for the Coleman Creek Watershed.

Landuse	Target Load Reduction (Percent)		
	Scenario 1	Scenario 2	Scenario 3
Forest	0	0	0
Harvested Forest	32	34	36
Pasture/Hay/Riparian Pasture	32	34	36
Crop	32	0	20
Developed (including barren land use)	32	0	20
Channel Erosion	32	34	0

Consideration of Critical Conditions

The GWLF model is a continuous simulation model that uses daily time steps for weather data and water balance calculations. The period of rainfall selected for modeling was from January 2000 to December 2012. This period is considered representative of typical weather conditions in Coleman Creek watershed, and included "dry," "normal," and "wet" years. The model, therefore, incorporated the variable inputs needed to represent critical conditions during low flow – generally associated with point source loads – and critical conditions during high flow – generally associated with nonpoint source loads. For Coleman Creek, nonpoint sources and in-stream erosion practically account for all of the total sediment loads to the stream. Therefore, the most important critical conditions are associated with high flows when sediments from nonpoint sources are carried into the stream with wet weather runoff.

Consideration of Seasonal Variability

Seasonal variations were explicitly incorporated in the approach through the use of the GWLF model which is a continuous simulation model. The Coleman Creek GWLF model used daily time steps for weather data and water balance calculations and monthly values for evapotranspiration cover coefficients, daylight hours/day, and rainfall erosivity coefficients.

Expression of Maximum Daily Loads

Table E.6 shows the TMDL expression as daily load following USEPA (2007) guidance.

Table E.6. TMDL Expression for Coleman Creek Watershed Expressed as Daily Load (metric tons/day).

TMDL (metric tons/day)	WLA (metric tons/day)	LA (metric tons/day)	MOS (metric tons/day)
11.05	0.22* *Future Growth WLA	9.73	1.10

Reasonable Assurance for Implementation

Several measures will be employed to provide reasonable assurance that the TMDL will be implemented. These include continuing monitoring of benthic macroinvertebrates and habitat in Coleman Creek to determine effectiveness of TMDL implementation; development of implementation plan and schedule in accordance with requirements of the Virginia's 1997 Water Quality Monitoring Information and Restoration Act; coordination with all other planning efforts such as with the implementation planning to address bacteria TMDL in Coleman Creek; and active participation of watershed stakeholders not only during the development of the TMDL but also its implementation.

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1.0 INTRODUCTION

1.1 Regulatory Guidance

Section 303(d) of the Clean Water Act and the Environmental Protection Agency(EPA)'s Water Quality Planning and Management Regulations (40 CFR Part 130) require states to develop Total Maximum Daily Loads (TMDLs) for waterbodies that are exceeding water quality standards. TMDLs represent the total pollutant loading that a waterbody can receive without violating water quality standards. The TMDL process establishes the allowable loadings of pollutants for a waterbody based on the relationship between pollution sources and in-stream water quality conditions. By following the TMDL process, states can establish water quality-based controls to reduce pollution from both point and non-point sources to restore and maintain the quality of their water resources (EPA, 2001).

1.2 Impairment Listing

This TMDL study is for Coleman Creek (Table 1.1) which is designated as impaired because it does not meet Virginia's water quality standards for aquatic life (benthic) use. Coleman Creek (i.e., its entire length of 8.42 miles) is listed as a result of bioassessment of the benthic macroinvertebrate. It was determined to be impaired in 2008 based on assessments at biological station 4ACLB001.90.

Coleman Creek (Figure 1.1) is a headwater stream in the Piedmont geographic province in Halifax County, Virginia and is a tributary of Hyco River. The Coleman Creek watershed is part of the Lower Dan River Watershed that is in the Roanoke River Basin.

Table 1.1. Summary of Impairment.

TMDL Watershed	Impaired Segment	305b Segment ID	Year First Listed
Coleman Creek	Coleman Creek	VAC-L74R_CLB01A06	2008

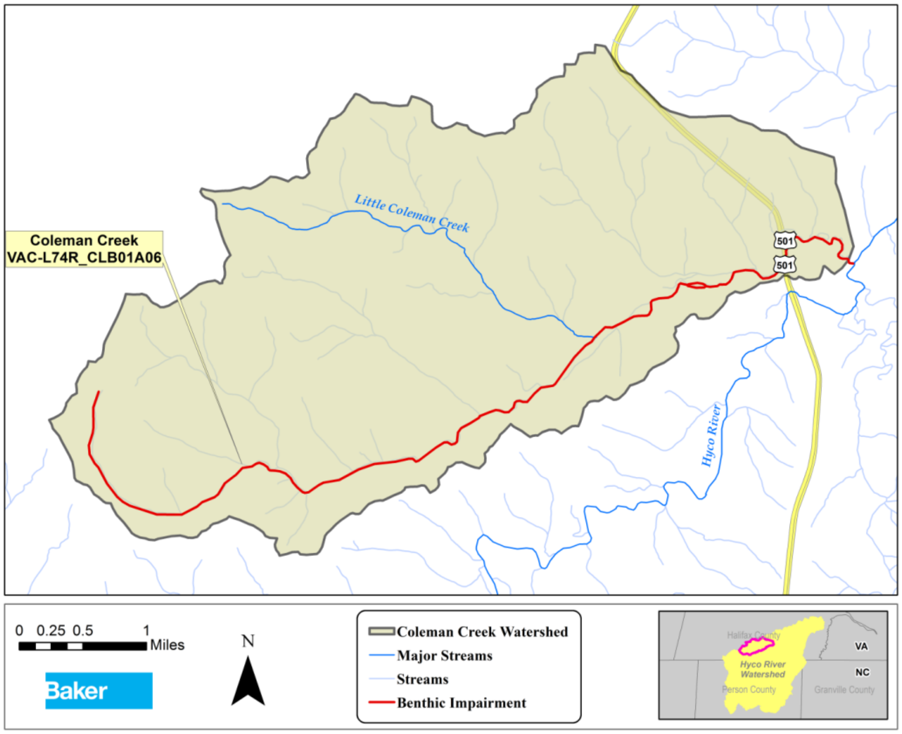

Figure 1.1. Coleman Creek Watershed.

1.3 Applicable Water Quality Standard and Designated Use

Water quality standards consist of designated uses for a waterbody and water quality criteria necessary to support those designated uses.

<u>Designated Uses</u>

According to Virginia Water Quality Standards (9 VAC 25-260-10): *"all state waters are designated for the following uses: recreational uses (e.g., swimming and boating); the propagation and growth of a balanced indigenous population of aquatic life, including game fish, which might be reasonably expected to inhabit them; wildlife; and the production of edible and marketable natural resources (e.g., fish and shellfish)."*

<u>Water Quality Criteria</u>

The General Standard defined in Virginia Water Quality Standards (9 VAC 25-260-20) provides general, narrative criteria for the protection of designated uses from substances that may interfere with attainment of such uses. The General Standard states: *"All state waters, including wetlands, shall be free from substances attributable to sewage, industrial waste, or other waste in concentrations, amounts, or combinations which contravene established standards or interfere directly or indirectly with designated uses of such water or which are inimical or harmful to human, animal, plant, or aquatic life."*

In Virginia, benthic macroinvertebrate communities are used as indicators of ecological condition and to determine support for the aquatic life designated use. A multimetric macroinvertebrate index, the Virginia Stream Condition Index (VSCI), is used to assess the aquatic life use status of wadeable freshwater streams and rivers in non-coastal areas of the state. The VSCI combines a series of biological metrics that are regionally calibrated to an appropriate reference condition (VADEQ, 2006), and combines them into a single value that is sensitive to a wide range of stressors. VSCI values less than 60 are deemed to be impaired, while those greater than or equal to 60 are considered to be healthy.

Coleman Creek was determined to violate Virginia's General Standard (9 VAC 25-260-20) based on assessments at biological station 4ACLB001.90 at Coleman Creek of the in-stream benthic macroinvertebrate community. This means that Coleman Creek does not fully support the aquatic life designated use for Virginia's waters (9 VA 25-260-10).

2.0 WATERSHED CHARACTERIZATION

2.1 Watershed Location

The Coleman Creek watershed is part of the Roanoke River basin and is in the western part of the 030101040606 12-digit hydrologic unit within the Lower Dan 8-digit hydrologic unit (Figure 1.1). The Coleman Creek watershed is approximately 7 miles south of the City of South Boston and lies entirely within Halifax County. US Route 501 runs through the east side of the watershed. The Coleman Creek watershed is 8,626 acres in size. Coleman Creek flows northeast to its confluence with the Hyco River. Coleman Creek is a tributary of the Roanoke River Basin, which flows into the Albemarle Sound in North Carolina.

2.2 Ecoregion

The Coleman Creek watershed is located entirely within the Northern Inner Piedmont (45e) sub-division of the Piedmont (45) ecoregion. Ecoregion 45e is a dissected upland composed of hills, irregular plains, and isolated ridges and mountains. Ecoregion 45e is characteristically underlain by highly deformed and deeply weathered Cambrian and Proterozoic feldspathic gneiss, schist, and melange. Streams have silt, sand, gravel, and rubble bottoms materials and bedrock is only occasionally exposed. Differences in stream gradient considerably affect fish habitat in the Piedmont. Loblolly – shortleaf pine forests are common (Woods et al., 1999).

2.3 Climate

Climate conditions for the Coleman Creek watershed can be characterized using data from meteorological observations made by the South Boston National Climatic Data Center station (USC00447925). This station is located within South Boston, Virginia approximately six miles north of the Coleman Creek watershed. Average annual precipitation at this station is 44.9 inches and the average annual daily temperature is 56.7°F. The highest average daily temperature of 76.8°F occurs in July while the lowest average daily temperature of 36.4°F occurs in January, as obtained from the 1981-2010 climate normals (NCDC, 2013).

2.4 Topography

Topography and relief data were obtained from the United States Geological Survey (USGS) National Data Set at a resolution of 1/3 arc-second (approximately, 10 meters). The region is characterized by low, rolling hills ranging in elevation from 320 feet to 500 feet above sea level.

2.5 Soil

As illustrated in Figure 2.1 and summarized in Table 2.1, the Coleman Creek watershed is comprised of a diversity of soils with its dominant soil, Spriggs-Rasalo complex, comprising 38.8 percent of the watershed. The next two most abundant soil types are Clifford sandy/clay loam and Rasalo-Orange complex at 26.2 and 13.6 percent, respectively.

The Spriggs-Rasalo complex consists of well-drained to moderately well-drained sandy loam atop clay loams on backslopes and shoulders of ridges in the Piedmont. The Spriggs are moderately deep while the Rasalo are deep. Spriggs and Rasalo are in the low and medium runoff classes, respectively. They formed from hornblende gneiss residuum. The Clifford series consist of sandy to clay loams that are well-drained with moderately high permeability. They formed on summits and shoulders of ridges in the Piedmont. Clifford soils are typically very deep and formed from granite gneiss residuum. The Rasalo-Orange complex consists of well-drained (Rasalo) to somewhat poorly drained (Orange) sandy loam atop clay loam with moderately high (Rasalo) to moderately low (Orange) permeability. The soil formed from a hornblende gneiss residuum on the summit and shoulders of Piedmont ridges (USDA-NRCS, 2009).

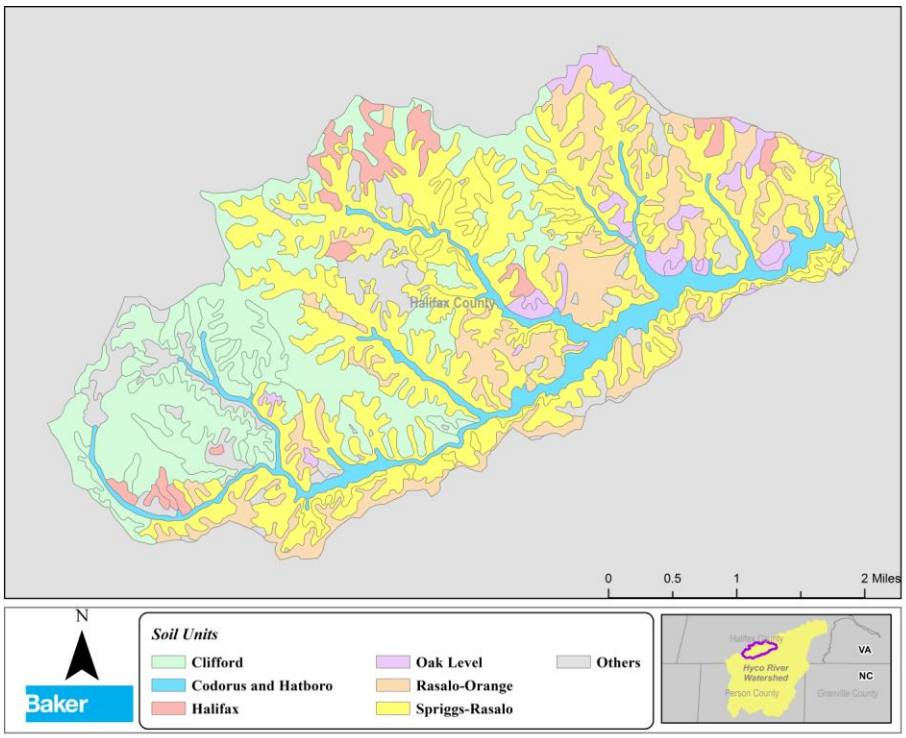

Figure 2.1. Soils in Coleman Creek watershed.

Table 2.1. Coleman Creek Watershed Soil Distribution.

Soil Name	Acres	Percent of Watershed
Spriggs-Rasalo	3,351	38.8
Clifford	2,264	26.2
Rasalo-Orange	1,172	13.6
Codorus and Hatboro	625	7.2
Oak Level	309	3.6
Halifax	304	3.5
Minnieville	196	2.3
Jackland-Orange	146	1.7
Nathalie	122	1.4
Fairview	94	1.1
Water	29	<1
Chewacla and Wehadkee	12	<1
Bentley	4	<1
Danripple	3	<1
Appomattox	2	<1
Total	**8,635**	**100**

2.6 Land Use

Land use categories for the Coleman Creek watershed were derived from the 2009 National Agricultural Statistics Service cropland data layer (USDA, 2009) for Virginia. Figure 2.2 and Table 2.2 show the land use distribution in the Coleman creek watershed. The main land use category in the watershed is forest, which comprises approximately 64 percent of the watershed, followed by 30 percent pasture and hay, 5 percent developed or urban green space, and less than 1 percent in cropland.

Table 2.2. Land Use Distribution in Coleman Creek Watershed.

Landuse	Coleman	Percent
Forest	5,497.0	63.72
Pasture	2,240.8	25.97
Urban Green Space	365.9	4.24
Hay	355.9	4.13
Wetland	56.2	0.65
Low Intensity Developed	47.6	0.55
Crop	35.1	0.41
Water	16.7	0.19
Medium Intensity Developed	6.7	0.08
Barren	2.9	0.03
High Intensity Developed	1.3	0.02
Total	**8,626.1**	**100.0**

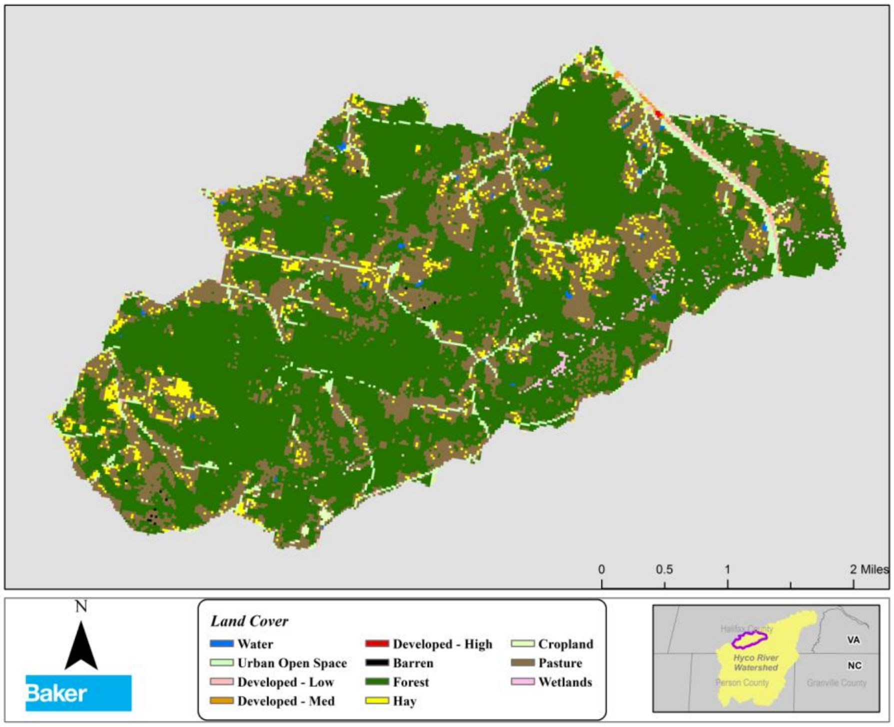

Figure 2.2. Coleman Creek Land Use.

2.7 Biological Data

The data for the bioassessments in Coleman Creek were based on VADEQ biological monitoring at two monitoring stations (4ACLB001.90 and 4ACLB004.14), which are shown in Figure 2.3 along with other VADEQ monitoring stations (primarily water quality stations). The aquatic life use of Coleman Creek is determined impaired based on 2006 surveys of the benthic macroinvertebrate community at Station 4ACLB001.90. The 2012 surveys at Station 4ACLB004.14 further confirm that Coleman Creek does not fully support aquatic life use as evidenced by the stressed conditions of the benthic macroinvertebrate community in that station.

The benthic macroinvertebrate data collected by VADEQ at the two Coleman Creek biological monitoring sites are summarized in Tables 2.3 and 2.4, and Figure 2.4. Each summary consists of a set that includes a taxa inventory table, a VSCI metrics and scores table, and a graph of VSCI scores. The biological monitoring data were provided by the VADEQ Blue Ridge Regional Office from the state's Environmental Data Analysis System (EDAS) database.

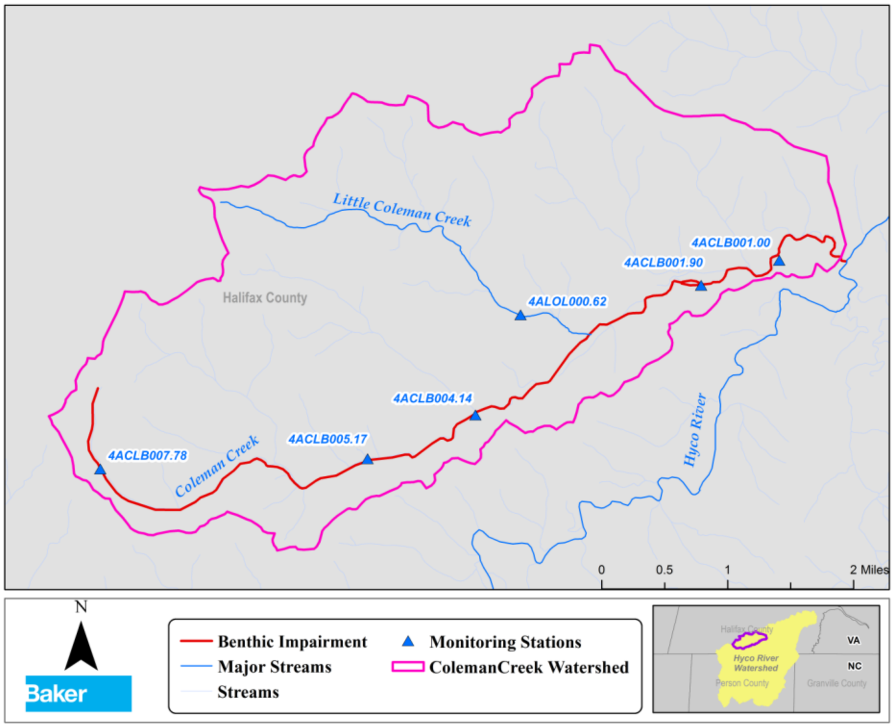

Figure 2.3. Biological and Water Quality Monitoring Stations.

From the taxa inventory shown in Table 2.3, the dominant species of benthic macroinvertebrates is the pollution-tolerant Chironomidae (non-biting midge). Abundance of Chironomids, which are filter feeders, may indicate higher levels of organic enrichment in the water column. Except in May 2006 data, a second dominant species that is more pollution-sensitive or indicative of better water quality was also observed. These include abundant individuals in the Leptophlebidae, Tipulidae, and Baetidae families. Leptophlebidae and Baetidae belong to the Ephemeroptera (mayfly) order, which is one of the three Ephemeroptera, Pleceptera, and Trichoptera (EPT) taxa. EPT taxa are associated with good water quality.

Table 2.3. Taxa Inventory for Coleman Creek.

Family	Tolerance Value	4ACLB001.90		4ACLB004.14	
		5/3/2006	10/20/2006	5/1/2012	11/6/2012
Perlidae	1	4			
Leptophlebiiidae	2		9		19
Simuliidae	3			1	
Tipulidae	3		20		
Philopotamidae	3		1		
Aeshnidae	3	2			
Caenidae	3	7	3	12	17
Dixidae	3			1	
Macromiidae	4				1
Baetidae	4	4		13	4

Family	Tolerance Value	4ACLB001.90		4ACLB004.14	
		5/3/2006	10/20/2006	5/1/2012	11/6/2012
Elmidae	4	6	1		1
Ephemerellidae	4		2	7	12
Heptageniidae	4	6		1	
Leptoceridae	4	1			
Phryganeidae	4				1
Gyrindae	5	3			
Corduliidae	5		1	1	1
Calopterygidae	5		1		
Ceratopogonidae	6			2	
Chironomidae	6	54	51	54	19
Ancylidae	6	1		1	
Hydropsychidae	6	2	2		
Simuliidae	6	5	3		
Tabanidae	6		1		
Oligochaeta	6			2	2
Gammaridae	6	2	8		
Corbiculidae	6			5	
Cambaridae	6				1
Crangonyctidae	6				1
Hydracarina	6			2	8
Polycentropodidae	6	1			
Sialidae	6				1
Planorbidae	7	1		1	
Sphaeridae	8	1			
Talitridae	8	18	2	4	20
Physidae	8	1		1	1
Lumbriculidae	8	2	2		
Asellidae	8	4	2		
Coenagrionidae	9	7	1	2	1
No. of species		21	17	20	17
Abundance		132	110	110	110
Additional Benthic Metrics					
Scraper/Filterer-Collector		14.9%	4.7%	13.2%	14.9%
%Filterer/Collector		76.5%	77.3%	83.5%	79.1%
%Haptobenthos		43.2%	26.4%	27.3%	52.7%
%Shredder		0.0%	18.2%	0.0%	0.9%

Dominant two species in each sample

Table 2.4 shows the individual VSCI metrics on a scale of 0-100, with 100 being the best possible score. The VSCI scores are plotted against the VSCI threshold in Figure 2.4. The primary biological effects are identified as those metrics scoring in the lowest 20th percentile. The primary biological effects in Coleman Creek are the low scores for the scraper functional group and for the sensitive members of the Plecoptera (stoneflies) and Trichoptera (case maker caddisflies) families.

Table 2.4. Virginia Stream Condition Data – Coleman Creek.

Station ID	4ACLB001.90		4ACLB004.14	
Collection Date	5/3/2006	10/20/2006	5/1/2012	11/6/2012
VSCI Metric Values				
Total Taxa	21	17	20	17
EPT Taxa	7	5	6	5
%Ephem	12.9	12.7	30.0	47.3
%PT-Hydropsychidae	4.5	0.9	0	0.9
%Scraper	11.4	0.9	10.9	11.8
%Chironomidae	40.9	46.4	49.1	17.3
%2Dom	60	35.5	54.6	64.6
HBI	5.98	5.11	4.16	4.36
VSCI Metric Scores				
Richness Score	95.5	77.3	77.3	77.3
EPT Score	63.6	45.5	36.4	45.5
%Ephem Score	21.0	20.8	48.9	77.1
%PT-H Score	12.8	2.6	0	2.6
%Scraper Score	22.0	1.8	7.1	3.5
%Chiron. Score	59.1	53.6	50.9	82.7
%2Dom Score	65.7	51.2	60.9	35.5
%MFBI Score	59.2	71.9	65.2	74.6
VSCI	**49.9**	**40.6**	**42.8**	**57.1**
VSCI Rating	**Stressed**	**Severe Stress**	**Stressed**	**Stressed**

- Primary biological effects

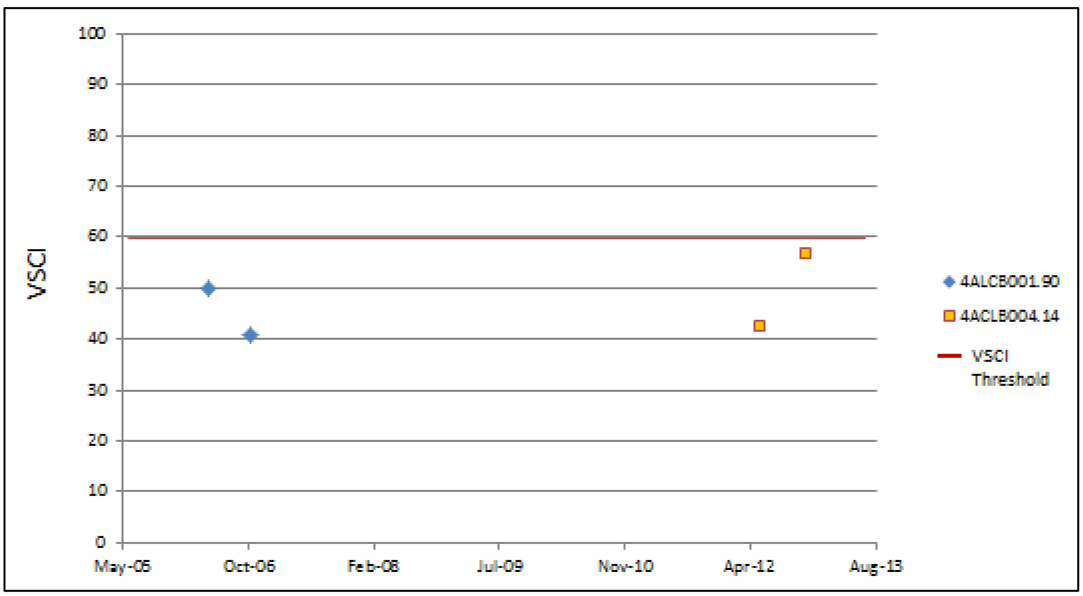

Figure 2.3. Coleman Creek VSCI Scores by Date.

2.8 VADEQ Habitat Data

Habitat data collected as part of the biological monitoring effort were also obtained from VADEQ through the EDAS database. Individual metrics are scored on a 0-20 basis using EPA rapid bioassessment protocols (Barbour et al., 1999), with scores of 0-5 rated as "poor"; scores of 6-10 as "marginal"; scores of 11-15 as "sub-optimal"; and scores of 16-20 as "optimal". Each stream bank is scored separately for three of the ten metrics: bank stability, vegetative protection, and riparian vegetation zone width. The maximum 10-metric total habitat score is 200; scores less than 120 are considered as sub-optimal, and those greater than 150 as optimal.

The habitat assessment data for Coleman Creek are shown in Table 2.5. The Pool Substrate metric received the lowest scores, and there was a distinct drop between the two sites, with the upstream site scored less than the downstream site. The assessments generally indicate that the channel stability is adequate, but, particularly in the case of the upstream assessment done in 2012, sediment deposition and available cover were notably poor. The assessment indicates that the source of the sediment problem in the upstream 2012 sample was not from the channel in the immediate vicinity of the benthic monitoring station.

Table 2.5. Habitat Evaluation Summary for Coleman Creek.

Metric	4ACLB001.90		4ACLB004.14	
Collection Date	5/3/2006	10/20/2006	5/1/2012	11/6/2012
Channel Alteration	15	18	15	16
Bank Stability*	16	16	16	14
Vegetative Protection*	12	18	16	16
Channel Flow Status	15	20	14	15
Riparian Vegetative Zone Width*	18	16	10	6**
Sediment Deposition	15	11	7**	7**
Epifaunal Substrate / Available Cover	10	10	7**	8**
Pool Substrate	14	9**	7**	7**
Pool Variability	11	11	12	11
Channel Sinuosity	12	15	8**	11
10-Metric Total Habitat Score* **	**138**	**144**	**112**	**111**

Notes:
*Metric is the sum of scores for both the left and right banks
**Score indicates marginal or poor habitat
***Total Habitat score: optimal > 150; suboptimal < 120

3.0 STRESSOR ANALYSIS

The purpose of the stressor analysis is to identify the most probable stressor that was present in the impaired water prior to the earliest bioassessment sample whose VSCI score was below 60. For Coleman Creek the stressors were present prior to the first biological sample in 2006. The stressors may be something that either directly affected the benthic community or indirectly affected the available habitat. The stressors may result from activities on the land directly draining to a stream segment, or from upstream tributaries that flow into any given segment.

3.1 Candidate Causes of Impairment

A list of candidate stressors was developed for the Coleman Creek impaired watershed and evaluated to determine the pollutant(s) responsible for the benthic impairment. The potential stressor checklist in Appendix A was used to evaluate known relationships or conditions that may show cause and effect between potential stressors and changes in the benthic community. An outline of available evidence was then summarized in Appendix B as the basis for each potential stressor. Depending on the strength of available evidence, the potential stressors were either eliminated, considered as “possible” stressors, or recommended as the “most probable” stressor(s). Candidate stressors included:

- Ammonia
- pH
- Temperature
- Metals
- Toxic organic compounds
- Nutrients (DO)
- Organic matter
- Streambed sedimentation
- Ionic strength (TDS, sulfates, conductivity).

3.2 Analysis of Evidence

In order to investigate and verify the stressor(s) causing the benthic impairment, available bioassessment data, water quality data, special study data, permitted point source data, and ancillary data were examined together with field observations. The extent and content of these data sources are summarized in Table 3.1. Evidence relevant to each candidate cause is summarized in Table 3.2.

Table 3.1. Available Monitoring Data.

Data Type/Location	Stream	Collection Period	Number of Samples	Description
Land Use Data				
Spatial data as displayed in Figure 1.4				
Virginia DEQ Biological (Benthic) Samples				
4ACLB001.90	Coleman Creek	May 2006, Oct 2006	2	Stream Condition Index scores and habitat assessments. [1]
4ACLB004.14		May 2012, Nov 2012	2	
Virginia DEQ Ambient Water Quality Samples				
4ACLB005.17	Coleman Creek	Jan 2011 to Dec 2011	23	Ambient physical and chemical water quality data.
4ACLB007.78		Oct 2000, Jul 2004 to Jun 2005	33	
4ACLB001.90		May 2006 to Oct 2006	98	
4ACLB001.00		Jan 2011 to Dec 2011	233	
4ALOL000.62	Little Coleman Creek	Oct 2000, Jul 2004 to Jun2005, Jan 2011 to Dec 2011	74	
Other Virginia DEQ Monitoring				
4ACLB001.90	Coleman Creek	May 2006	1	Sample analyzed for 250 metals and organic compounds in stream sediment.
Virginia DEQ Permitted Point Sources				
VPDES permits and DMR data			0	
Domestic Permits			4	Three residences and one storage business.
VAHWQP Household Drinking Water Analyses				
Halifax County		2013	75	Summary of household well drinking water quality analyses.
Virginia DCR Land Disturbing Permits				
Halifax County				Disturbed area in acres. Data not available. County did not respond to data request.

[1]Site moved upstream in 2012 for better access and to avoid beaver impoundments.

Table 3.2. Evidence Relevant to Each Candidate Cause.

Candidate Cause	Relevant Evidence
Ammonia	VADEQ ambient data
pH	VADEQ ambient data, VAHWQP drinking water analyses
Temperature	VADEQ ambient data, habitat metrics
Metals	VADEQ periodic channel bottom sediment and water column analyses, VAHWQP drinking water analyses
Toxic organic compounds	VADEQ periodic channel bottom sediment analyses, permit data
Nutrients	VADEQ ambient data, species counts, biological metrics, ancillary data, VAHWQP drinking water analyses
Dissolved Oxygen	VADEQ ambient data, species counts
Organic Matter	VADEQ ambient data
Streambed Sedimentation	Habitat metrics and total scores, field observations, RBS, ancillary data
Ionic Strength	VADEQ ambient data

3.2.1 Virginia DEQ Ambient Data

Virginia DEQ conducted monitoring at five stations in the Coleman Creek watershed beginning in 2000. Field physical measurements were conducted during each sampling and included dissolved oxygen, temperature, pH, and conductivity. Chemical parameters typically included nitrogen components (ammonia, total Kjeldahl nitrogen, nitrate, and nitrite), total phosphorus, total filterable residue (suspended solids), chloride, and Escherichia Coli (e. Coli and fecal coliform). Table 3.3 shows the average nutrient concentrations measured from the five monitoring stations.

Table 3.3. Average Nutrient Concentrations.

			Total Nitrogen (mg/L)		Nitrate Nitrogen (mg/L)		Nitrite Nitrogen (mg/L)		Total Kjehdahl Nitrogen (mg/L)		Total Phosphorus (mg/L)		TN:TP Ratio	TKN:TP Ratio
Station ID	Beg. Date	End Date	No.	Avg.	No.	Avg.	No.	Avg.	No.	Avg.	No.	Avg.		
4ACLB001.00	1/19/2011	12/6/2011	12	0.76	12	0.06	12	<0.01	12	0.7	2	0.025	18.4	0.92
4ACLB001.90	5/3/2006	10/20/2006	1	0.42	2	0.045	2	<0.01	1	0.4	12	0.042		
4ACLB007.78	10/25/2000	6/29/2005	-	-	1	<0.04	1	<0.01	1	<0.1	13	0.028		
4ACLB005.17	1/19/2011	12/6/2011	8	0.21	-	-	-	-	-	-	8	0.018		
4ALOL000.62	10/25/2000	12/6/2011	14	0.34	1	<0.04	1	<0.01	1	0.25	1	0.044		

Figures 3.1 to 3.11 show time-series scatter plot of ambient water quality monitoring data from October 2000 to December 2011 for the following parameters:

- Temperature
- Dissolved oxygen
- pH

- Specific conductivity
- Total nitrogen
- Kjeldahl nitrogen
- Ammonia
- Total Phosphorus
- Total nonfilterable residue
- E. coli
- Turbidity

Where applicable, water quality standards are indicated on the plots. All stream segments are considered Class III Nontidal Waters, Coastal and Piedmont Zones. As can be noted in Figures 3.1 to 3.11, the following water quality standard exceedances were observed.

- Five samples for dissolved oxygen in 2011 at station 4ACLB001.00
- A sample for pH was less than 6.0 in 2006 at station 4ACLB001.90
- Nine samples for E. coli in 2005 at stations 4AL0L000.62 and 4ACLB007.78 and in 2011 at stations 4ACLB005.17 and 4ACLB001.00. Note that E. coli is not a potential benthic stressor.

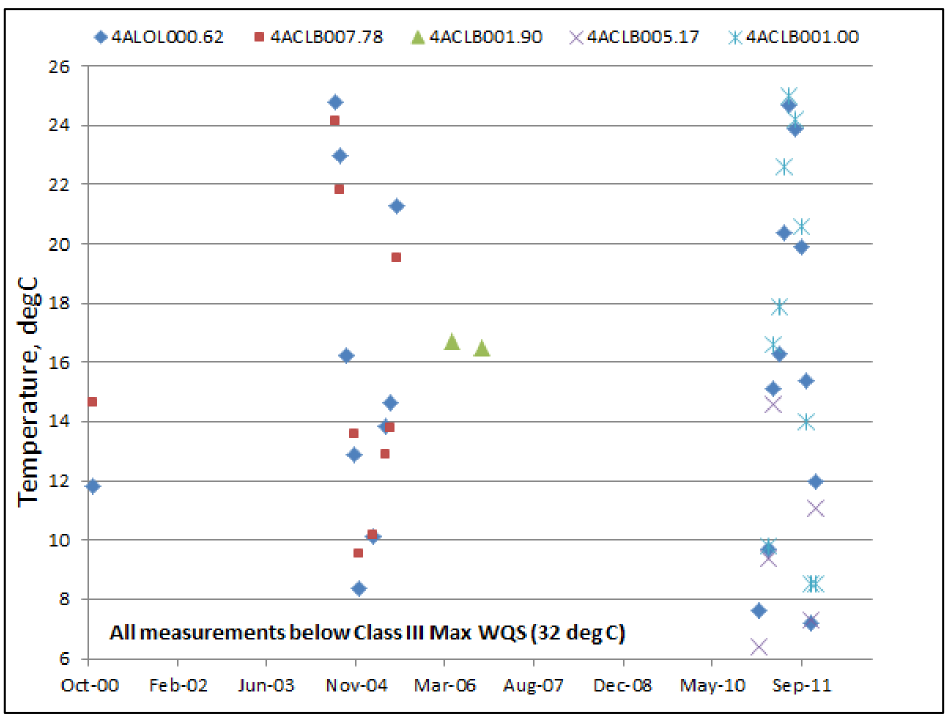

Figure 3.1. Field Temperature.

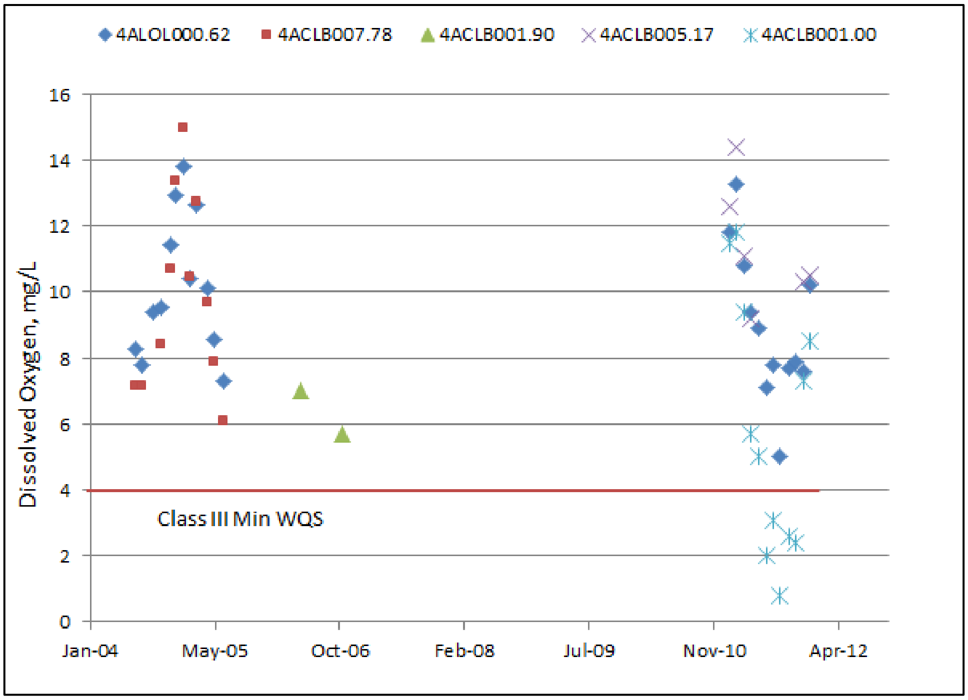

Figure 3.2. Field Dissolved Oxygen.

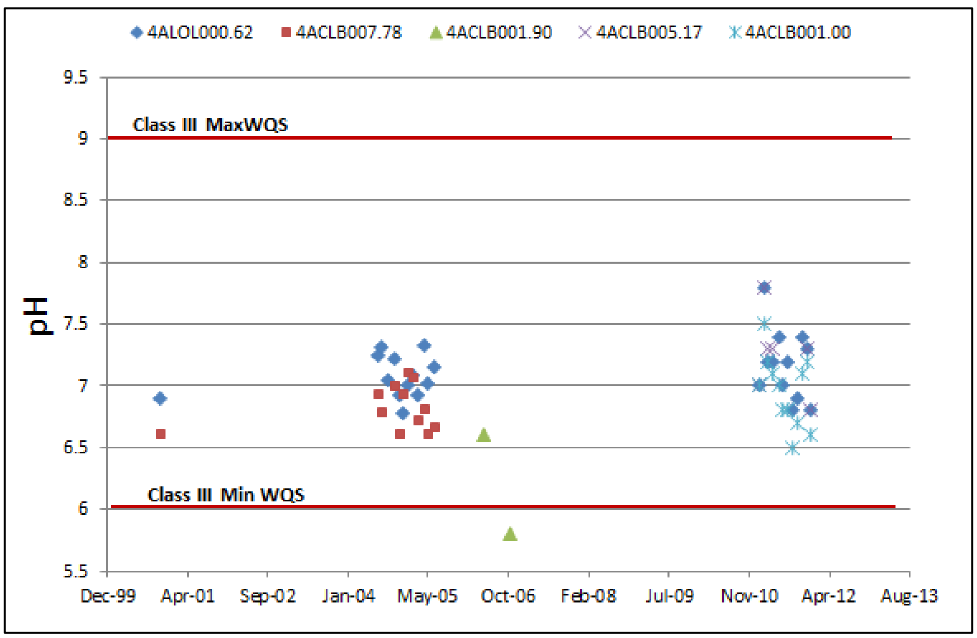

Figure 3.3. Field pH.

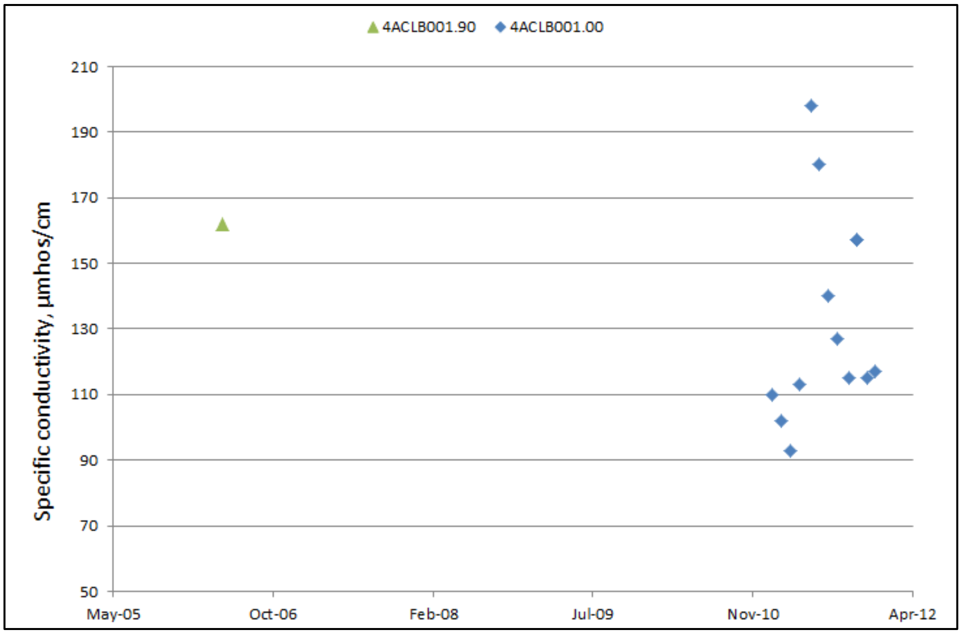

Figure 3.4. Field Specific Conductance.

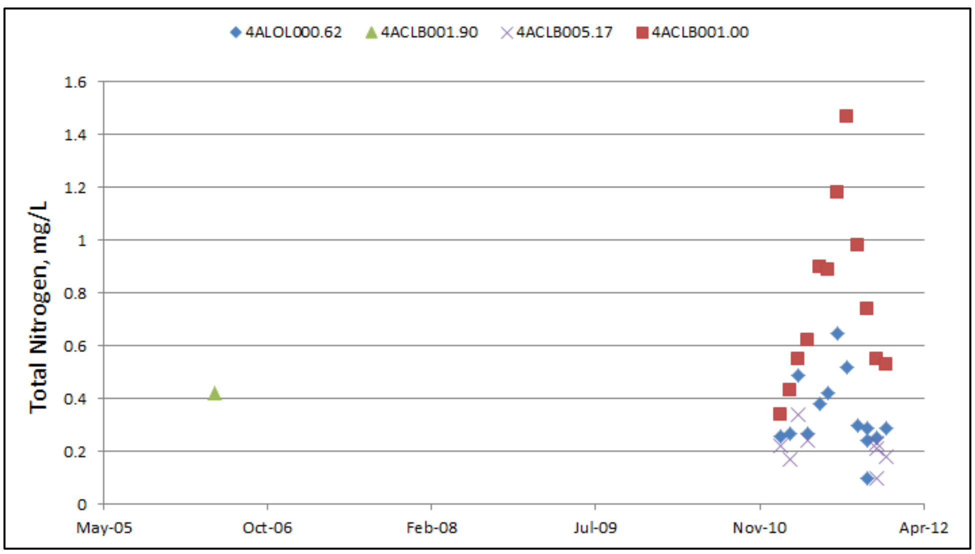

Figure 3.5. Total Nitrogen.

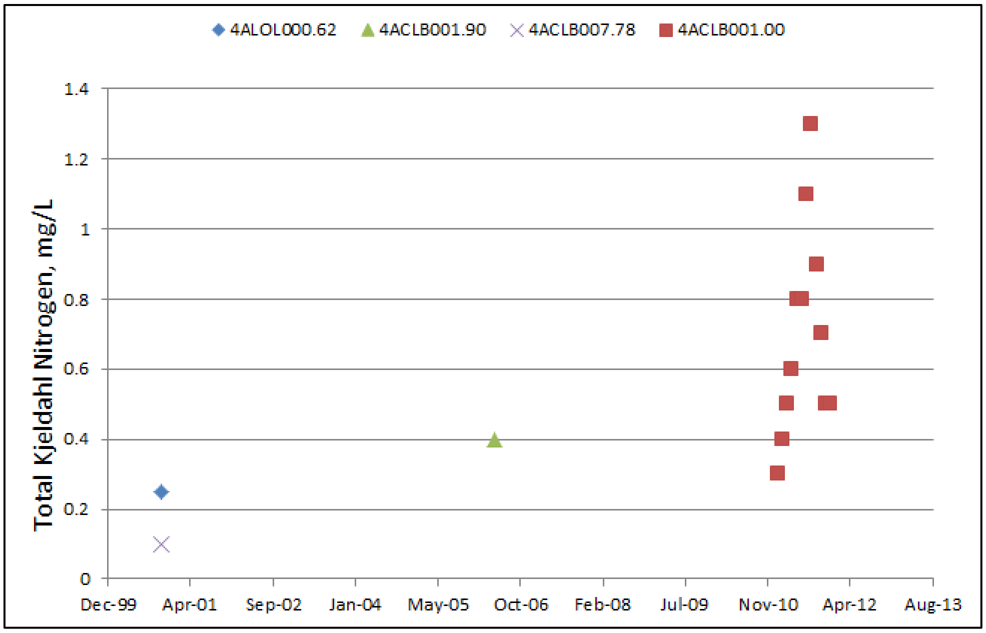

Figure 3.6. Total Kjeldahl Nitrogen (Ammonia plus Organic N).

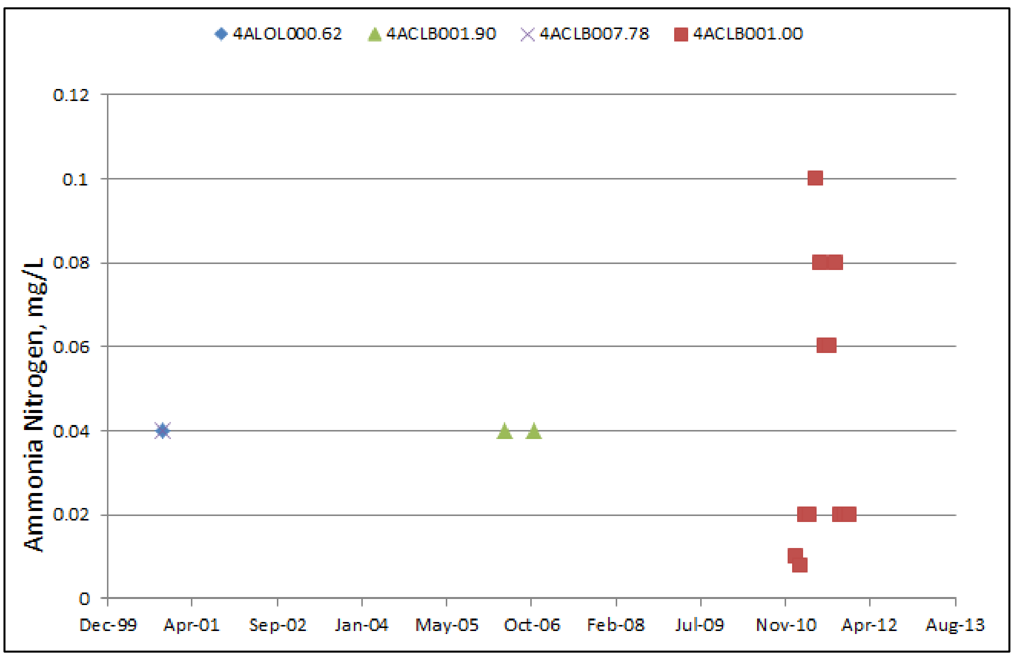

Figure 3.7. Ammonia.

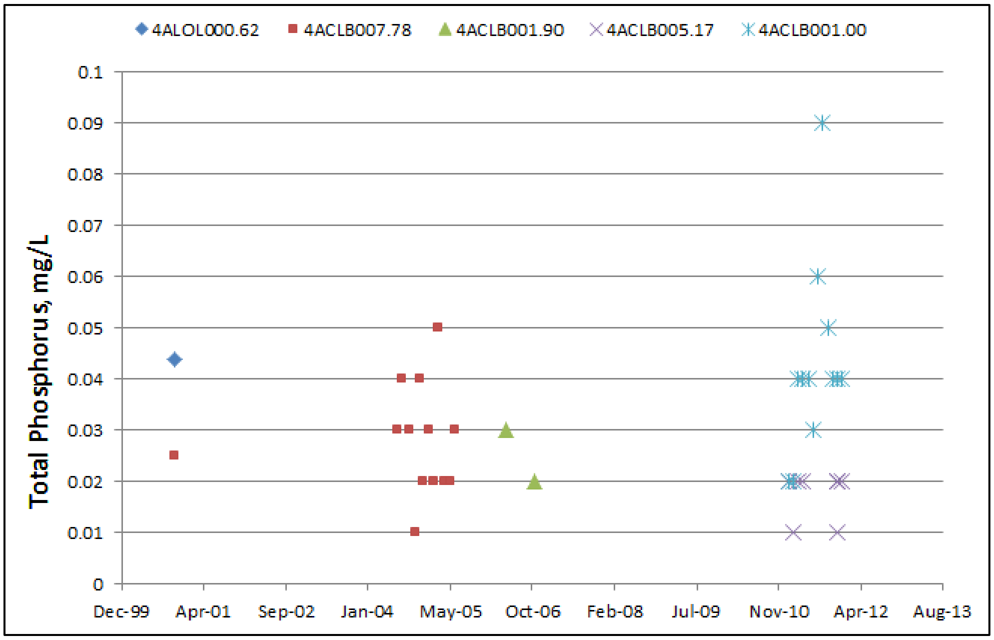

Figure 3.8. Total Phosphorus.

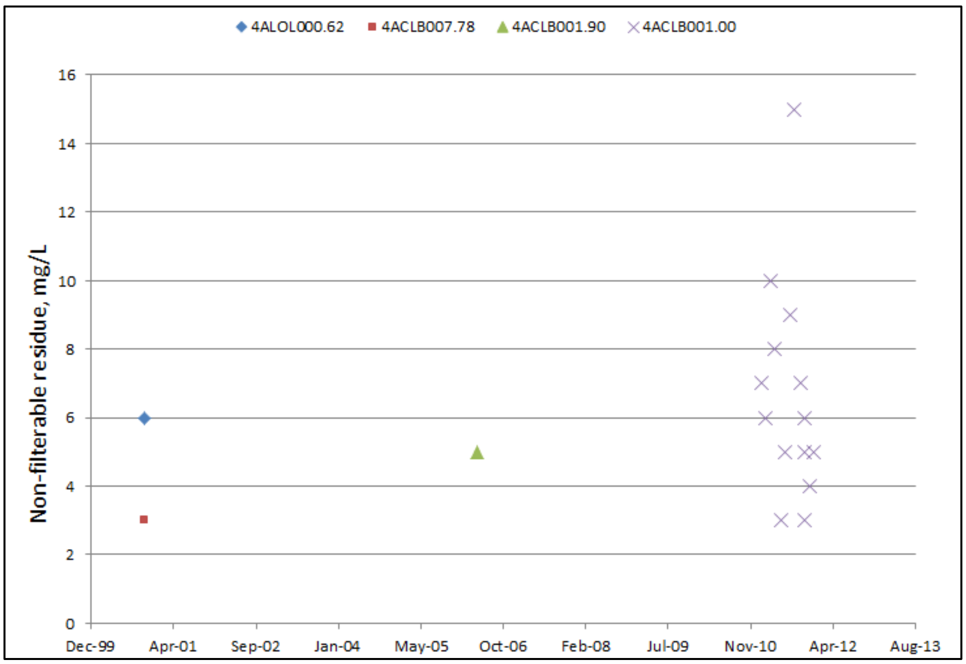

Figure 3.9. Non-filterable Residue.

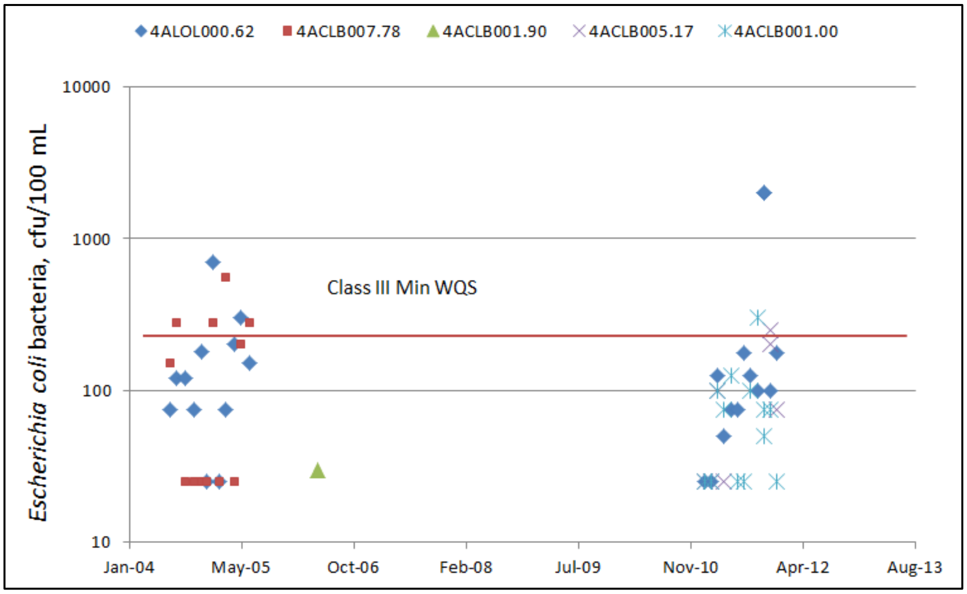

Figure 3.10. Escherichia coli.

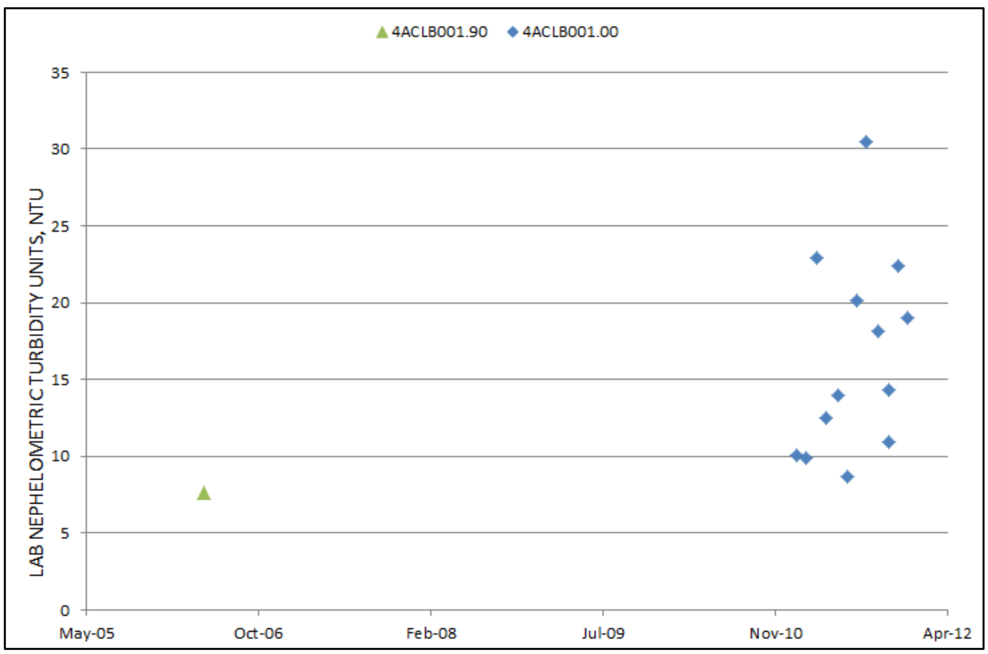

Figure 3.11. Turbidity.

3.2.2 Virginia DEQ Toxicity Data

Virginia DEQ conducted one sampling exercise at Station 4ACLB001.90 on Coleman Creek on May 3, 2006, to assess toxicity from metals in the water column and a suite of 250 parameters in the bed sediment. The sediment analysis included measurement of metals, polycyclic aromatic hydrocarbons (PAHs), PCBs, and semi-volatile organics. Table 3.4 shows metals in the water column and applicable benchmarks which indicate levels at which impacts may be seen. Aquatic life benchmarks are for organisms that live in the water column, such as fish, not in the substrate, such as macroinvertebrates. Table 3.4 shows the measured water column concentrations in Coleman Creek are well below all criteria except for the arsenic measurement which exceeded the chronic screening criteria for invertebrates. Heavy metals such as mercury, chromium, cadmium, arsenic and lead that are present in streams and rivers can damage aquatic insects at low concentrations. The metals tend to accumulate in the gills and muscles of aquatic organisms. Dissolved metals have been identified as important predictors of stream health. In the context of water quality criteria, dissolved metals are typically treated independently; however there is strong evidence that metals have a cumulative effect (Clements et al., 2000). The Cumulative Criterion Units (CCU) metals index accounts for this additive effect by standardizing each dissolved metal's concentration. The metals are summed together and the result is the CCU Metals Index score. When the CCU Metals Index is above 2, the cumulative effect is considered likely to harm aquatic life (Clements et al., 2000). The CCU score for the samples collected from Coleman Creek in May 2006 is 0.43, which is well below the threshold of concern. To the extent that it can be verified, no known current or previous sources of metals, toxics, or hazardous cleanup sites are in the watershed.

Table 3.4. Water Column Dissolved Metals Analysis from 5/3/2006 and Screening Criteria from USEPA, 2002.

Parameter	Measured Value	Aquatic Life - Freshwater		Invertebrates	
		Acute	Chronic	Acute	Chronic
Antimony (µg/L)	U*				
Arsenic (µg/L)	0.3	340	150	3.6	0.17
Barium (µg/L)	40.3				
Calcium (mg/L)	13.4				
Chromium (µg/L)	0.1	570	10	15	2.5
Copper (µg/L)	2.0	13	9	20	8
Iron (µg/L)	425				
Manganese (µg/L)	512				
Magnesium (mg/L)	6.0				
Nickel (µg/L)	0.6	180	20	105	52
Mercury (µg/L)	U*	1.4	0.77		
Zinc (µg/L)	1.2	120	120	51	10

*U denotes for parameter analyzed but not detected.

Tables 3.5 and 3.6 show toxic constituents from the sediment monitoring that were above the detection limits, compared with various screening criteria for probable effects concentrations and threshold effects concentrations. VADEQ uses screening values known as Probable Effects Concentrations (PECs) for freshwater comparison. PECs are peer-reviewed, consensus-based sediment quality values above which adverse effects will probably be observed in aquatic organisms (MacDonald et al., 2000). TECs are peer-reviewed, consensus-based sediment quality values below which adverse effects are unlikely to be observed in aquatic organisms.

Table 3.5 shows the sediment toxic constituent concentrations measured above the laboratory detection limits in Coleman Creek are well below all PEC criteria. Not only were the probable effects concentrations not exceeded, but the threshold effects concentrations shown in Table 3.6 were also not exceeded. Tables 3.5 and 3.6 show there is nothing of concern in these data.

Table 3.5. Channel Bottom Sediment Analysis (only Measured Values above Detection Limit shown) and Probable Effects Screening Criteria (USEPA, 2002).

Parameter	Measured Value	Probable Effects Concentration*					
		PEL	SEL	TET	ERM	PEL-HA28	PEC
Metals (mg/kg)							
Chromium	12.1	90	110	100	145	120	111
Copper	8.33	197	110	86	390	100	149
Lead	6.12	91.3	250	170	110	82	128
Zinc	38.6	315	820	540	270	540	459
PAHs (ug/kg)							
Benzo(a)pyrene	15.3	782	14400	700	2500	320	1450
Semi-volatile Organics (ug/kg)							
Butyl Benzyl Phthalate	24.9						10900
Bis(2-Ethylhexyl) Pththalate	19.6						180
Di-n-butyl Phthalate	47.6						6470
*PEC is consensus-based. PEL, SEL, TET, ERM, PEL-HA28 are other published probable effect screening criteria.							

Table 3.6. Channel Bottom Sediment Analysis Criteria (only Measured Values above Detection Limit shown) and Threshold Effects Screening (USEPA, 2002).

Parameter	Measured Value	Threshold Effects Concentration*					
		TEL	LEL	MET	ERL	TEL-HA28	TEC
Metals (mg/kg)							
Chromium	12.1	37.3	26	55	80	26	43.4
Copper	8.33	35.7	16	28	70	28	31.6
Lead	6.12	35	31	42	35	37	35.8
Zinc	38.6	123	120	150	120	98	121
PAHs (ug/kg)							
Benzo(a)pyrene	15.3	31.9	370	500	400	32	150
Semi-volatile Organics (ug/kg)							
Butyl Benzyl Phthalate	24.9						
Bis(2-Ethylhexyl) Pththalate	19.6						
Di-n-butyl Phthalate	47.6						
*PEC is consensus-based. PEL, SEL, TET, ERM, PEL-HA28 are other published probable effect screening criteria.							

3.2.3 Other Virginia DEQ Monitoring Data

Previous Virginia DEQ stressor analysis studies have used the log relative bank stability (LRBS) test to quantify whether sedimentation is a potential problem. LRBS numbers around zero indicate the stream is stable. Increasingly negative LRBS numbers indicate excess sediment while positive LRBS numbers signify sediment removal. LRBS scores less than -1 (i.e., increasingly negative) are considered sub-optimal, while scores greater than -0.5 (i.e., increasingly positive) are considered optimal.

VADEQ assessed sediment on 10/20/2006 at Station 4ACLB001.90 and found 57 percent sand and 43 percent hardpan (Table 3.7). The LRBS was a positive 0.76, indicating there is not a sediment accumulation problem in this reach. However, VADEQ staff believe that this is a sediment transport reach because of the high percentage of substrate that is hardpan (i.e., sediment has not been deposited by streamflow).

Table 3.7. Relative Bed Stability Analysis Results.

StationID	Date	Percent Sand	Percent Hardpan	LRBS
4ACLB001.90	10/20/2006	57.1%	42.9%	0.76

3.2.4 Virginia DEQ Permits in Coleman Creek

- There are four domestic (general) discharge permits for single-family homes in the watershed (Table 3.8).
- There are no National Pollutant Discharge Elimination System (NPDES) permitted discharges in the watershed.

Table 3.8. Permitted Domestic Discharges in Coleman Creek Watershed.

Permit No	Facility	Classification	Receiving Stream
VAG404045	Domestic Sewage	Active	Coleman Creek UT
VAG407229	Domestic Sewage	Active	UT to Coleman Creek
VAG407257	Domestic Sewage	Active	UT to Coleman Creek
VAG404044	Domestic Sewage	Active	Coleman Creek

Domestic discharges have low volume (less than 1,000 gallons per day) and should not contribute any pollutants of concern, and it is very unlikely that they are a source of the benthic impairment.

3.2.5 305(b)/303(d) Monitored Exceedances – Combined Report

In addition to the biological monitoring previously reported and the bacteria exceedances being addressed by the separate Hyco River study, the following water quality standards exceedances have been reported in the biennial integrated 305(b)/303(d) report to EPA (Table 3.9):

- pH: One of two samples exceeded the standard limits at the downstream site, 4ACLB001.90 in 2006.

Not included in the exceedances were dissolved oxygen measurements at 4ACLB001.00 in 2011. According to the data provided by Virginia DEQ, six of twelve measurements included dissolved oxygen concentrations at or below the standard of 4.0 mg/L. These data are outside of the period considered in the 2012 integrated report (ends in 2010), but they will be considered in the 2014 integrated report and will list an impairment for dissolved oxygen.

Table 3.9. Summary of 303(d)/305(b) Integrated Report Monitored Exceedances.

					Conventional Water Column Data									Other Water Column Data				Sediment				Benthic	Nutrients			
					Temperature			Dissolved Oxygen			pH			Metals		Other Toxics		Metals		Other Toxics		Biomon	Total Phosphorus			
Year	Station ID	Assessment Unit ID (ID305B)	Station Type	VAHU6	Exceed	Samples	Status	Exceed	Samples	Status	Exceed	Samples	Status	Exceed	Status	Exceed	Status	Exceed	Status	Exceed	Status	Status	Exceed	Samples	Status	Comments
2006	4ACLB001.90	VAC-L74R_CLB01A06	FPM, B	RD72																						No data in this report
	4ACLB005.17	VAC-L74R_CLB01A06	SS	RD72	0	9	S	0	9	S	0	9	S			0	S						0	9	S	PRO Hog Farm Special Study & Follow-up
	4ACLB007.78	VAC-L74R_CLB01A06	SS	RD72	0	8	S	0	8	S	0	8	S			0	S						0	9	S	PRO Hog Farm Special Study & Follow-up
	4ALOL000.62	VAC-L74R_LOL01A06	SS	RD72	0	9	S	0	9	S	0	9	S			0	S						0	9	S	PRO Hog Farm Special Study & Follow-up
2008	4ACLB001.90	VAC-L74R_CLB01A06	FPM, B	RD72	0	2	S	0	2	S	1	2	IN	0	S	0	S	0	S	0	S	IM				2006 Probabilistic Monitoring
	4ACLB005.17	VAC-L74R_CLB01A06	SS	RD72	0	12	S	0	12	S	0	12	S			0	S									PRO Hog Farm Special Study & Follow-up
	4ACLB007.78	VAC-L74R_CLB01A06	SS	RD72	0	11	S	0	11	S	0	11	S			0	S									PRO Hog Farm Special Study & Follow-up
	4ALOL000.62	VAC-L74R_LOL01A06	SS	RD72	0	12	S	0	12	S	0	12	S													PRO Hog Farm Special Study & Follow-up
2010	4ACLB001.90	VAC-L74R_CLB01A06	FPM, B	RD72	0	2	S	0	2	S	1	2	IN	0	S	0	S	0	S	0	S	IM	0	2	S	2006 Probabilistic Monitoring
	4ACLB005.17	VAC-L74R_CLB01A06	SS	RD72	0	12	S	0	12	S	0	12	S			0	S						0	12	S	PRO Hog Farm Special Study & Follow-up
	4ACLB007.78	VAC-L74R_CLB01A06	SS	RD72	0	11	S	0	11	S	0	11	S			0	S						0	12	S	PRO Hog Farm Special Study & Follow-up
	4ALOL000.62	VAC-L74R_LOL01A06	SS	RD72	0	12	S	0	12	S	0	12	S			0	S			0	S					PRO Hog Farm Special Study & Follow-up
2012	4ACLB001.90	VAC-L74R_CLB01A06	FPM, B	RD72	0	2	S	0	2	S	1	2	IN	0	S	0	S	0	S	0	S	IM				2006 Probabilistic Monitoring
	4ACLB005.17	VAC-L74R_CLB01A06	SS	RD72	0	6	S	0	6	S	0	6	S			0	S									PRO Hog Farm Special Study & Follow-up
	4ACLB007.78	VAC-L74R_CLB01A06	SS	RD72	0	6	S	0	6	S	0	6	S			0	S									PRO Hog Farm Special Study & Follow-up
	4ALOL000.62	VAC-L74R_LOL01A06	SS	RD72	0	6	S	0	6	S	0	6	S			0	S			0	S					PRO Hog Farm Special Study & Follow-up

3.2.6 Household Drinking Water Analysis, Halifax County

The Virginia Household Water Quality Program (VAHWQP) conducted a drinking water clinic in Halifax County in 2013, where homeowners brought in well, spring, and/or tap water samples for water quality testing and analysis. These samples can be considered to be representative of the broader background groundwater quality in the area. The results are shown in Table 3.10.

Table 3.10. Virginia Household Water Quality Program for Halifax County.

Halifax County Household Water Quality Testing Program
Sample Date 8/14/2013
Water Chemistry Analysis Results
Total No. of Samples: 75

Constituent	Detection Limit (DL)	EPA recommended limit or range	Average	Minimum	Maximum	Exceeding EPA recommendation No.	Exceeding EPA recommendation %
Iron (mg/l)	0.0109	0.3	0.13	DL	3.369	8	10.7%
Manganese (mg/l)	0.000	0.05	0.012	0.	0.195	3	4.0%
Hardness (mg/l)	0.017	120 – 180 (hard)	52.8	0.	173.7	0	0.0%
		>180 (very hard)					
Sulfate (mg/l)	0.30	250	6.	DL	75.	0	0.0%
Fluoride (mg/l)	0.10	2 (SMCL)	0.14	DL	0.88	0	0.0%
		4 (MCL)					
Total Dissolved Solids (mg/l)	1.0	500	125.	22.	383.	0	0.0%
pH	N/A	Min. 6.5	6.5	5.3	8.1	38	50.7%
		Max 8.5				0	0.0%
Copper (mg/l)	0.0007	First Draw: 1.3	1.181	DL	9.771	22	29.3%
		Flush: 1.3	0.187	DL	7.55	1	1.3%
Sodium (mg/l)	0.0017	20	12.27	2.2	103.1	6	8.0%
Nitrate-N (mg/l)	0.005	10	1.304	DL	7.933	0	0.0%
Arsenic (mg/l)	0.0011	First Draw: 0.01	0.001	DL	0.022	1	1.3%
		Flush: 0.01	0.001	DL	0.019	1	1.3%
Lead (mg/l)	0.000	First Draw: 0.015	0.01	0.	0.049	19	25.3%
		Flush: 0.015	0.001	0.	0.016	1	1.3%
Total Coliforms (MPN/100 ml)	0.3	0.0	397.	DL	22,749.	36	48.0%
E. coli (MPN/100 ml)	0.3	0.0	0.	DL	14.	6	8.0%

Bacteriological Analysis Results Total No. of Samples: 75		
Bacteria ABSENT	Total Coliform PRESENT	E. coli PRESENT
39	36	6
52.0%	48.0%	8.0%
Notes: Averages are calculated with values below the detection limit (DL) set equal to the detection limit.		

3.2.7 Recent Implementation of BMPs in the Watershed

According to Halifax County Soil & Water Conservation District and NRCS when consulted in November 2013 about recent implementations of BMPs in the watershed, livestock exclusion fencing was installed along 6,200 feet of Upper Coleman Creek approximately five years ago, and eight acres of cropland were reforested.

3.3 Analysis of Candidate Stressors for Coleman Creek

The suspected sources of the benthic impairment in Coleman Creek were listed as habitat impacts from sediment deposition in the stream in the 2008 list of impaired waters. All 8.42 miles of Coleman Creek were listed for impaired aquatic life in 2008 based on a 2006 survey of the benthic macroinvertebrate community. A follow-up survey was conducted in 2012 at a site more than two miles upstream from the 2006 survey. The 2012 monitoring indicated a slightly less pollution tolerant community.

A list of candidate stressors was developed and evaluated for Coleman Creek in order to determine the pollutant(s) responsible for the benthic impairment. The potential stressor checklist in Appendix A was used to evaluate known relationships or conditions that may show associations between potential stressors and changes in the benthic community. Depending on the strength of available evidence, the potential stressors were eliminated, considered as "possible" stressors, or recommended as the "most probable" stressor. Candidate stressors included ammonia, pH, temperature, metals, toxic sediment organic compounds, nutrients, organic matter, streambed sedimentation, and ionic strength. The evaluation of each candidate stressor is discussed in the following sections.

3.3.1 Eliminated Stressors

3.3.1.1 Ammonia

Elevated in-stream ammonia concentrations are toxic to many fish and benthic macro-invertebrate species. Monitoring results showed low ammonia concentrations. Therefore, ammonia was eliminated as a stressor candidate for Coleman Creek.

3.3.1.2 pH

Benthic macroinvertebrates require a specific pH range of 6.0 to 9.0 to live and grow. Changes in pH may adversely affect the survival of benthic macroinvertebrates. Anthropogenic sources that may alter in-stream levels of pH include, treated wastewater, mining discharge, and urban runoff. The natural occurrence of wetlands, forests, or certain naturally exposed and eroding geologic formations also may cause exceedance of the pH standard. Only one in-stream pH measurement out of 57 total measurements from all the Coleman Creek watershed monitoring sites was below the minimum or above the maximum standards. Therefore, pH was eliminated from further consideration.

3.3.1.3 Temperature

Elevated temperatures can stress benthic organisms and provide sub-optimal conditions for their survival. Coleman Creek is classified as a Class III Nontidal Waters, Coastal and Piedmont Zones stream, with a maximum temperature standard of 32°C. No exceedances of the temperature standard were recorded at any VADEQ ambient monitoring station. Therefore, temperature was eliminated as a candidate stressor.

3.3.1.4 Metals

Toxicity testing of metals in the water column and bed sediment was completed in May 2006. None of the analytes were above benchmark criteria for levels that indicate possible effects on the invertebrate community. Consequently, there is no evidence to suggest that metals are a candidate stressor and these were eliminated from further consideration.

3.3.1.5 Toxic Sediment Organic Compounds

Toxic substances by definition are not well tolerated by living organisms. The presence of toxics as a stressor in a watershed may be supported by very low numbers of any type of organisms, low organism diversity, exceedances of freshwater aquatic life criteria or consensus-based Probable Effect Concentrations (PEC) for organic compounds, by low percentages of the shredder population, reports of fish kills, or by the presence of available sources. No samples were deficient in total numbers of organisms, although the percent shredder population was typically very low (less than 1 percent in three surveys, and one survey at 18 percent). None of the sediment organic compounds tested for were above threshold-effects levels, let alone the probable-effects levels. Therefore, toxic sediment organic compounds were eliminated as a possible stressor.

3.3.1.6 Ionic Strength

Total dissolved solids (TDS) include inorganic salts, organic matter, and other dissolved materials in water. Elevated levels of TDS cause osmotic stress and alter the osmoregulatory functions of organisms (McCulloch et al., 1993). All specific conductivity measurements at the VADEQ monitoring station on Coleman Creek were below the VADEQ reference screening value of 500 mhos/cm and were relatively low, averaging 134.7 µmhos/cm. Therefore, there was no evidence to support ionic strength as a possible cause of the benthic impairment, and it was eliminated as a candidate stressor.

3.3.2 Possible Stressors

3.3.2.1Nutrients

High nutrient loading and in-stream levels can lead to an increased growth of algae, eutrophication, and low dissolved oxygen concentrations that may adversely affect pollution-intolerant benthic macroinvertebrates. Dissolved oxygen may become particularly low when algae die off in mass, or at night when algae respire.

The primary nutrients measured in Coleman Creek include nitrogen and phosphorus. Sources of nitrogen include groundwater, residential wastewater, atmospheric deposition, and agricultural runoff (i.e., fertilizer and animal waste). The available evidence suggests nitrogen concentrations are not elevated in Coleman Creek. In the Halifax County Household Water Quality Testing Program, none of the 75 samples have nitrate-N concentrations exceeding the EPA recommendation of 10 mg/L. Additionally, VADEQ's adopted reference value of 1.5 mg/L nitrate-N was never exceeded in 16 in-stream samples. In fact, the average nitrate-N concentration was 0.06 mg/L in 12 samples in 2011 at Station 4ACLB001.00.

EPA's recommended TN nutrient criteria for ecoregion 45, based on the 25th percentile of reference-quality streams, is 0.41 mg/L (USEPA, 2000). The average concentration of 35 Coleman Creek samples is 0.46 mg/L and only two measurements were greater than 1.0 mg/L. Less than 1.0 mg/L is in the optimal range of thresholds for stressor indicators (VADEQ, 2006a). This indicates Coleman Creek nitrogen levels are not reference quality according to EPA's recommended criteria, but they are categorized near the optimal range of thresholds for stressor indicators.

Phosphorus is more often sediment-bound or otherwise derived from agricultural runoff. VADEQ's draft "observed effects" threshold for phosphorus is 0.2 mg/L. For stressor indicator thresholds, the optimal range is below 0.02 mg/L and the suboptimal range is greater than 0.05 mg/L. In 36 total phosphorus samples taken from the Coleman Creek watershed, the highest concentration was 0.09 mg/L and the average concentration was 0.031 mg/L. This average is just above EPA's recommended TP nutrient criteria for ecoregion 45 of 0.03 mg/L. Therefore, phosphorus does not appear to be a candidate stressor.

The riparian vegetation width scores from the 2012 benthic monitoring were 6 and 10, which are in the poor to marginal range. Low riparian vegetation zone width metric scores indicate the potential for increased nutrient contributions from surface runoff as all samples were rated as poor or marginal.

Dissolved oxygen levels were noticeably low at the downstream monitoring station (4ACLB001.00) in 2011. In fact, it is likely that Coleman Creek will be added to the 2014 303(d) list for dissolved oxygen based on five of 12 measurements being below the standard of 4.0

mg/L. However, based on the observed nutrient levels, it appears that the low dissolved oxygen is probably more the result of organic enrichment rather than high nutrient levels.

3.3.2.2 Organic Enrichment

High loading or creation of organic matter can lead to low in-stream dissolved oxygen concentrations, which may lead to stressed benthic macroinvertebrate communities as indicated by a high proportion of pollution intolerant species. Potential sources of organic matter in Coleman Creek include household wastewater discharges, direct livestock access to streams, agricultural runoff from areas receiving manure, and die off of in-stream algal blooms.

Ninety-two percent of the calculated total nitrogen levels were in TKN form, although the total nitrogen concentrations were relatively low. Moreover, the vast majority of TKN in Coleman Creek comes from organic N, which can be attributed to organic matter such as agricultural waste, decaying vegetation, and algae. Note TKN is composed of organic nitrogen plus ammonia. Table 3.11 shows that the average TKN concentration from 12 samples taken at the downstream site in 2011 was 0.70 mg/L and the average ammonia concentration from those samples was 0.04 mg/L.

Table 3.11. Average Nitrogen Concentrations from 12 Samples at Station 4ACLB001.00 in 2011.

Nitrogen Component	Concentration (mg/L)
TN	0.76
TKN	0.70
Ammonia	0.04
Nitrate	0.06
Nitrite	<0.01

Further evidence supporting organic matter as a probable stressor includes the fact that high numbers of Chironomidae were found in all benthic surveys which is indicative of sites that have organic enrichment. Also, low ratios of scrapers to filterer-collectors: 15, 5, 13, and 15 percent in four surveys (listed chronologically) is indicative of abundant suspended organic matter used as a food source by the filterer-collectors. The percent MFBI scores were also high, particularly in the two 2012 surveys, which further supports organic matter as a possible stressor.

As discussed earlier, low dissolved oxygen levels were observed in 2011 at Station 4ACLB001.00, which is located about a mile downstream of the benthic monitoring station 4ACLB001.90. No data is available to support the occurrence of low dissolved oxygen concentrations at the benthic monitoring locations. In fact, the dissolved oxygen data measured in 2006 in station 4ACLB001.90 did not violate the water quality standard. The available evidence suggests that the low dissolved oxygen concentrations are limited to the downstream monitoring station. Moreover, because of beaver impoundments observed in the area, it is possible that the low dissolved oxygen is due to natural swamp conditions.

3.3.3 Probable Stressor

3.3.3.1Streambed Sedimentation

High levels of sedimentation can impair benthic macroinvertebrate communities by burying their habitat. Since Coleman Creek is a sand bed stream, there is not an issue of embeddedness, where sediment fills the interstitial spaces between gravel and cobble substrate. However, it is possible that sediment can bury other habitat, including leaf packs and woody debris. Potential sources of sediment include streambank and channel-bottom erosion, agricultural runoff, forest runoff if clear-cutting is practiced, and construction sites. The potential sources are listed in decreasing likelihood. Channel erosion may be caused by a number of factors resulting in channel degradation (deepening/widening), including changes in rainfall-runoff patterns (likely due to increased impervious surface in the watershed), livestock trampling of streambanks, and/or riparian buffer clearing.

The percentages of haptobenthos, or those aquatic organisms that live closely applied to, or growing on, submerged surfaces, were between 26 and 53 percent. The lower percentages of haptobenthos occurred when the corresponding SCI was also low. Additionally, the habitat metric scores related to sediment were low in the 2012 survey. The document to develop the SCI for Virginia noted habitat scores of less than 7 (out of 20) for channel alteration, bank stability, sediment deposition, epifaunal substrate, and riparian vegetation are indicative of sites whose physical quality is considered stressed. None of these habitat metric scores were below 10 in the 2006 assessment, but sediment deposition (both at 7) and epifaunal substrate (one at 7, one at 8) were at the cited stressed levels in 2012. This indicates accumulated sediment is lowering the haptobenthos percentages and the SCI scores.

The LRBS siltation index score does not support a sediment accumulation problem. However, VADEQ staff believe that the analysis was conducted in a sediment transport reach because of the high percentage of substrate that is hardpan (i.e., sediment has not been deposited by the streamflow).

While there were no high non-filterable residue (TSS) concentrations reported at the VADEQ ambient monitoring site for Coleman Creek, no samples were taken during runoff events when sediment is most likely to be transported. However, sediment is supported as a most probable stressor by the low habitat metric scores related to sediment.

During the TMDL study, stream walks of two reaches of Coleman Creek were conducted. The first reach included approximately 1,000 linear feet upstream and 300 feet downstream from

Paradise Road. The 2012 benthic monitoring was conducted just downstream from Paradise Road. The second reach included approximately 1,000 feet upstream from Traynham Grove Road, which is roughly one mile upstream along Coleman Creek from Paradise Road. The streambanks along Coleman Creek in these reaches were on the average four feet high, though they reached five or six feet in some locations. The banks were also nearly vertical and did not have much vegetation on them. The streambanks along Coleman Creek in these two reaches were observed to be definitely active sediment sources.

3.3.4 Conclusion

Streambed sedimentation is selected as the most probable stressor causing the benthic impairment of Coleman Creek. Nutrient/organic enrichment is a less likely cause of impairment. The low dissolved oxygen levels measured in 2011 were recorded downstream from the benthic monitoring locations and are possibly due to natural swamp conditions. There is no evidence for the occurrence of low dissolved oxygen concentrations at the benthic monitoring locations.

4.0 SETTING TMDL ENDPOINT

Since there are no in-stream water quality criteria for sediment in Virginia, an alternate methodology was used to establish a TMDL endpoint that would represent the non-impaired condition. A reference watershed approach was used to set allowable sediment load (or TMDL) in the Coleman Creek watershed.

The reference watershed approach pairs two watersheds, one whose streams are supportive of their designated uses and one whose streams are impaired. The reference watershed is selected on the basis of similarity of land use, topography, ecology, and soils characteristics with those of the impaired watershed. This approach is based on the assumption that reduction of the stressor loads in the impaired watershed to the level of the loads in the reference watershed will result in the elimination of the benthic impairment.

Of the several potential reference watersheds provided by VADEQ, Winn Creek watershed in Halifax County was evaluated to be the most similar to the Coleman Creek watershed. Based on two biological assessments conducted in spring and fall of 2010, Winn Creek was evaluated to be fully supporting its benthic macroinvetebrate community with VSCI scores of 68.6 and 70.6, respectively. Winn Creek is approximately 12 miles north of Coleman Creek as illustrated in Figure 4.1. Table 4.1 compares the watersheds based on pertinent watershed characteristics used as criteria for selecting the reference watershed.

Models of both Coleman Creek and Winn Creek watersheds were created to estimate the existing annual sediment loads. The land use areas in Winn Creek were adjusted using the ratio of the total areas of Coleman Creek and Winn Creek watersheds to account for the difference in the watershed size. The TMDL endpoint was set as equal to the estimated sediment load from the area-adjusted Winn Creek watershed.

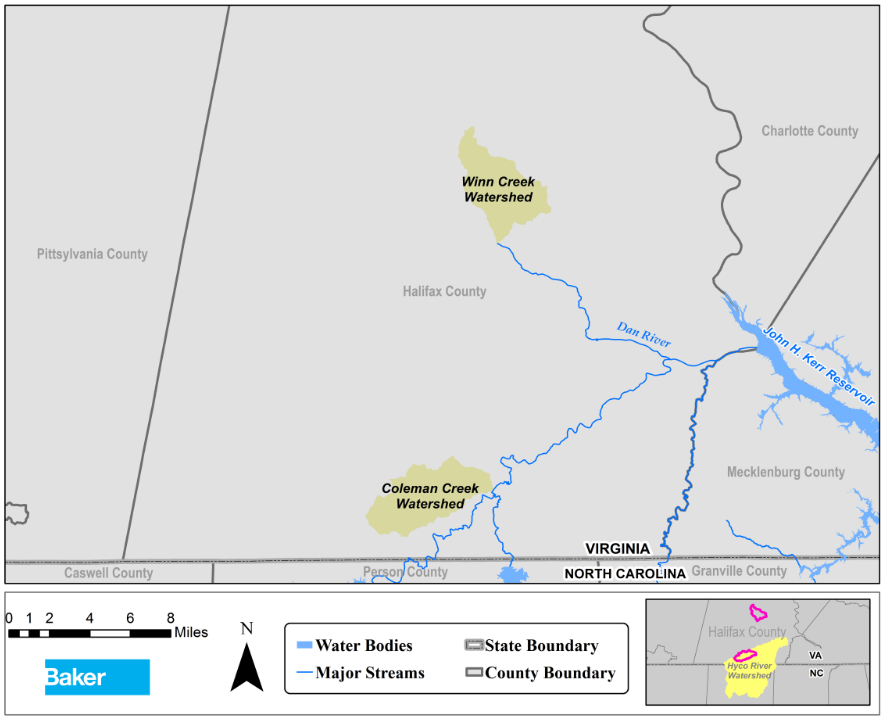

Figure 4.1. Location of Coleman Creek and Winn Creek Watersheds.

Table 4.1. Comparison of Coleman Creek and Winn Creek Watersheds.

Criteria	Description
Ecoregion	Both Coleman Creek and Winn Creek watersheds are located entirely within the Northern Inner Piedmont (45e) sub-division of the Piedmont (45) ecoregion. The stream ecology of the watersheds is expected to be similar since they are in the same ecoregion.
Topography	Both watersheds are characterized by low rolling hills. Average slope is 6.48 percent for Coleman Creek watershed and 6.67 percent for Winn Creek watershed.
Land Use	Both watersheds have similar land distribution with forest comprising about 60 percent of the total watershed area and pasture more than 20 percent. Both watersheds are primarily rural with residential/commercial areas comprising less than 0.5 percent of the total watershed area.
Soils	Both watersheds include several common soil series the most predominant of which is Clifford, which is about 26 percent in the Coleman Creek watershed and 46 percent in the Winn Creek watershed. The Clifford series consist of sandy to clay loams that are well drained with moderately high permeability.
Watershed Size	Coleman Creek and Winn Creek watersheds are similar in size. The Coleman Creek watershed is approximately 8,626 acres and the Winn Creek watershed is approximately 7,878 acres.
Location	The watersheds are in close proximity to each other. The downstream most points of the watersheds (i.e., mouth of the watersheds) are approximately 12 miles apart.

5.0 Modeling Approach

This chapter describes the hydrologic and the water quality modeling approach adopted to estimate the sediment loads for both the Coleman Creek and Winn Creek watersheds to support the development of a sediment TMDL for Coleman Creek, the entire length of which is listed as impaired for a stressed benthic macroinvertebrate community.

5.1 Modeling Goals and Model Selection

The goal of the modeling task is to select and develop a calibrated model that can be used as a primary decision support tool for developing a sediment TMDL for Coleman Creek. The model should have the following capabilities:

i. Account for spatial watershed characteristics for the impaired segment including topographic, hydrographic, land use/land cover, soil, and other environmental features
ii. Account for spatial and temporal characteristics of meteorological, flow, and water quality data
iii. Account for point and non-point pollution sources of sediment and their contributions,
iv. Quantitatively estimate the in-stream pollutant loads under various hydrologic conditions,
v. Allow for calibration and validation by comparing simulated data with observed values under different climatic and watershed conditions, and
vi. Evaluate pollutant reduction scenarios to achieve TMDL allocations.

The Generalized Watershed Loading Function model (GWLF) was selected because it meets the abovementioned capabilities and it has become the model of choice for developing sediment TMDLs in Virginia.

5.2 Model Setup

The Coleman Creek watershed model is based on GWLF2010, which is a version developed at Virginia Tech and based on the Visual Basic version of GWLF, developed by Barry Evans at Penn State and often referred to as the PSU version. All GWLF parameter values were estimated following guidance provided in the GWLF User's Manual (Haith et al., 1992) and GWLF2010 modeling convention document prepared by Gene Yagow, and adjusted based on additional information when appropriate.

5.2.1 Watershed Delineation

A single watershed was delineated to represent the drainage area of the Coleman Creek watershed since there are no water quality data or any other more detailed landscape and hydrologic information that can be used as a basis to justify subdividing the watershed into subwatersheds.

5.2.2 Land Use Distribution

Table 5.1 shows the modeled land use distribution within the Coleman Creek watershed. This includes estimates for harvested forest and riparian pasture. Harvested forest is assumed 3.0 percent of the total forested land cover. Riparian pasture is pasture adjacent to and within 100 feet of perennial streams.

Table 5.1. Modeled Land Use Distribution in the Coleman Creek Watershed.

Landuse	Area (acres)	Percent
Forest	5,332.1	61.81
Pasture	2,204.3	25.55
Urban Green Space	365.9	4.24
Hay	355.9	4.13
Harvested forest	164.9	1.91
Wetland	56.2	0.65
Low Intensity Developed	47.6	0.55
Riparian Pasture	36.5	0.42
Crop	35.1	0.41
Water	16.7	0.19
Medium Intensity Developed	6.7	0.08
Barren	2.9	0.03
High Intensity Developed	1.3	0.02
Total	8,626.1	100.0

5.2.3 Hydrographic Data

The hydrographic data that represents the stream networks and contain stream characteristics were generated from the NHD flow lines during the delineation of the Coleman Creek watershed. The total length of streams in the watershed based on NHD is 210,738 feet (39.9 miles) of which 90,739 feet (17.2 miles) are classified as perennial. Based on the USGS Virginia Piedmont Regional Curve, the average mean channel depth is estimated to be 2.35 feet.

5.2.4 Weather Data

GWLF uses daily temperature in degrees Centigrade and daily total precipitation in centimeters for model weather inputs. A station at South Boston, VA, GHCND USC00447925 was initially selected to provide these data. South Boston is approximately seven miles north of the Coleman Creek watershed. A 14-year period of record beginning in April 1999 was used.

In order to further improve the hydrologic calibration, the precipitation data from the Tropical Rainfall Measuring Mission (TRMM) of National Aeronautics and Space Administration (NASA) and the Japan Aerospace Exploration Agency (JAXA) were used. When available, the daily total precipitation was derived from the three-hour precipitation data of TRMM and was used instead of the data available from the South Boston station. It should be noted that the TRMM data, which provides continuous local precipitation data at three hour intervals was used in the Hyco River watershed modeling using HSPF. TRMM data (version 7) provide gridded estimates on a 3-hour temporal resolution and a 0.25-degree by 0.25-degree spatial resolution in a global belt extending from 50 degrees South to 50 degrees North latitude. These data are extensively quality checked and validated using ground based precipitation measurements. As noted later in the hydrologic calibration section, the HSPF simulated flows of the Hyco River and its tributaries (including Coleman Creek) were used as the basis for calibrating the GWLF model in the absence of monitored flow data in Coleman Creek. HSPF was the model used for developing bacteria TMDLs for the Hyco River watershed. It is therefore important for the GWLF model to use the same precipitation data set used for HSPF during the calibration.

5.2.5 Sediment Loads from Surface Runoff

During runoff events, sediment loading occurs from both pervious and impervious surfaces in the watershed. For pervious areas, soil is detached by rainfall impact or shear stresses created by overland flow and transported by overland flow to nearby streams. This process is influenced by vegetative cover, soil erodibility, slope, slope length, rainfall intensity and duration, as well as land management practices. During periods without rainfall, dirt, dust, and fine sediment build up on impervious areas through dry deposition, which is then subject to washoff during rainfall events. Pervious area sediment loads were modeled using a modified USLE erosion detachment algorithm, monthly transport capacity calculations, and a sediment delivery ratio in the GWLF model to calculate loads at the watershed outlet. Impervious area sediment loads were modeled in the GWLF model using an exponential buildup-washoff algorithm.

Table 5.2 shows the data used to model sediment loads from surface runoff in Coleman Creek watershed.

Table 5.2. Model Parameters by Land Use for the Coleman Creek Watershed.

Landuse	CN	K	S	L	LS	C	P	KLSCP
UGR	71.5	0.28	4.36	71.57	3.48	0.027	1.00	0.02651
Developed (Low)	69.1	0.28	3.57	76.50	2.87	0.020	1.00	0.01608
Developed (Medium)	73.8	0.28	3.15	79.29	2.25	0.020	1.00	0.01262
Developed (High)	0.0	0.00	0.00	103.63	0.38	0.020	1.00	0.00000
Barren	0.0	0.00	0.00	103.63	0.38	0.510	1.00	0.00000
Forest	58.7	0.29	7.37	55.38	6.75	0.002	1.00	0.00290
Harvested forest	64.6	0.29	7.37	55.38	6.75	0.015	1.00	0.02899
Pasture	71.6	0.29	5.96	62.44	5.38	0.040	1.00	0.06208
Riparian Pasture	81.9	0.29	5.65	64.10	5.09	0.480	1.00	0.70480
Hay	71.3	0.29	5.18	66.73	4.65	0.010	1.00	0.01348
Crop	80.5	0.30	5.05	67.45	4.54	0.049	1.00	0.06737

Landuse	CN	K	S	L	LS	C	P	KLSCP
Wetland	65.8	0.28	5.06	67.39	4.55	0.002	1.00	0.00191

The model parameters included in Table 5.2 are further described below:

Curve Number: The SCS curve number (CN) is used in calculating runoff associated with a daily rainfall event, evaluated using SCS TR-55 guidance. The curve number was determined by intersecting the land use with the soil data.
USLE K factor: The soil erodibility factor was calculated as an area-weighted average of all component soil types.
USLE LS factor: This factor is calculated from slope and slope length measurements by land use. Slope is evaluated by GIS analysis, and slope length is calculated as an inverse function of slope.
USLE C factor: The vegetative cover factor for each land use was evaluated following GWLF manual (Haith et al., 1992), Wischmeier and Smith (1978), and Hession et al. (1997).
USLE P factor: The BMP practice factor that accounts for human efforts to reduce sediment loading in a given land use (e.g., no till practices or forestry BMPs). P values equal to one were used for all source areas.
Daily sediment buildup rate on impervious surfaces: The daily amount of buildup on impervious surfaces on days without rainfall, assigned using GWLF manual guidance.

5.2.6 Sediment Loads from Channel and Streambank Erosion

Streambank erosion was modeled within the GWLF model using a modification of the routine included in the AVGWLF version of the GWLF model (Evans et al., 2001). This routine calculates average annual streambank erosion as a function of percent developed land, average area-weighted curve number (CN) and K-factors, watershed animal density, average slope, streamflow volume, mean channel depth, and total stream length in the watershed as shown in Table 5.3. The Livestock population for Coleman Creek was estimated from 2007 Census of Agriculture data for the entire Halifax County.

Table 5.3. Model Parameter Values for Estimating Channel and Streambank Erosion for Coleman Creek Watershed.

Parameter	Value
Percent Developed Land	4.89
Animal Density	0.046
Area-Weighted Runoff Curve Number	57.6
Area-Weighted Soil Erodibility	0.236
Area-Weighted Slope	6.48 %
Total Stream Length	80,739 ft (27,664 m)
Mean Channel Depth	2.35 ft (0.72 m)

The model parameters included in Table 5.3 are further described below (from Evans et al., 2003):

Percent Developed land: percentage of the watershed with urban-related land uses – defined as all of the road, and the impervious portion of low intensity developed (LDI), medium intensity developed (MDI), and high-intensity developed (HDI) land uses.

Animal density: calculated as the number of beef and dairy 1000-lb equivalent animal units (AU) divided by the watershed area in acres.

Curve Number (CN): area-weighted average value for the watershed.

Soil Erodibility (K): area-weighted USLE soil erodibility factor for the watershed.

Slope: mean percent slope for the watershed.

Stream length: calculated as the total stream length of natural perennial and intermittent stream channels from the NHD stream layer, in meters.

Mean channel depth (m): calculated from relationships developed USGS for the Virginia Piedmont region, of the general form, $y = a * A^b$, where y = mean channel depth in feet, and A = drainage area in square miles (USDA-NRCS, 2005). A multiplier for the bank height ratio was incorporated to account for field measurements.

5.2.7 Hydrologic and Sediment Transport Parameters

Table 5.4 shows additional watershed-wide hydrologic and sediment transport parameters that are required by the GWLF model. These parameters were adjusted within allowable range values during calibration.

Table 5.4. Watershed-wide Hydrologic and Sediment Transport Model Parameters.

Parameter	Values
Recession coefficient	0.0771/day
Seepage coefficient	0.07
Leakage coefficient	0.055
Sediment delivery ratio	0.1552
Unsaturated soil moisture capacity	6.0 in (15.2 cm)
Erosivity coefficient (Oct – Mar)	0.303
Erosivity coefficient (Apr – Sep)	0.133

The model parameters included in Table 5.4 are further described below (from Evans et al., 2003):

Recession coefficient (day^{-1}): The recession coefficient is a measure of the rate at which streamflow recedes following the cessation of a storm, and is approximated by averaging the ratios of streamflow on any given day to that on the following day during a wide range of weather conditions, all during the recession limb of each storm's hydrograph. This parameter was evaluated using the following relationship from Lee et al. (2000):

Recession Coefficient = 0.045+1.13/(0.306+DA), where DA = drainage area in square kilometers.

Seepage coefficient: The seepage coefficient represents the fraction of flow lost as seepage to deep storage.

Leakage coefficient: The leakage coefficient represents the fraction of infiltration that bypasses the unsaturated zone through macro-pore flow. An increase in this coefficient, initially set to zero, decreases ET losses and increases baseflow.

Sediment delivery ratio (SDR): The fraction of erosion – detached sediment – that is transported or delivered to the edge of the stream, calculated as an inverse function of watershed size (Evans et al., 2001)

SDR = 0.000005 * DA – 0.0014* DA + 0.198

Unsaturated Soil Moisture Capacity (SMC, cm): The amount of moisture in the root zone, evaluated as a function of the area-weighted soil type attribute - available water capacity.

Erosivity Coefficient: This is a regional coefficient used in Richardson's equation for calculating daily rainfall erosivity. Figure B-1 in the GWLF manual (Haith et al., 1992) was used to calculate the erosivity coefficient. Each region is assigned separate coefficients for the months October-March, and for April-September.

Other parameters that were not included in the tables, but are required by the GWLF model, are described below.

Initial Conditions:

- Initial unsaturated storage (cm): Initial depth of water stored in the unsaturated (surface) zone.
- Initial saturated storage (cm): Initial depth of water stored in the saturated zone.
- Initial snow (cm): Initial amount of snow on the ground at the beginning of the simulation.
- Antecedent Rainfall for each of 5 previous days (cm): The amount of rainfall on each of the five days preceding the first day in the weather file.

Monthly Parameters:

- Month: Months were ordered, starting with April and ending with March – in keeping with the design of the GWLF model.
- ET CV: Composite evapotranspiration cover coefficient, calculated as an area-weighted average from land uses within each watershed. Table B-8 in the GWLF manual (Haith et al., 1992) provided the approximate values for each land use.
- Hours per Day: Mean number of daylight hours calculated based on latitude and Table B-9 in GWLF manual (Haith et al., 1992).

5.3 Hydrologic Calibration

In the absence of observed flow data in Coleman Creek, the Coleman Creek GWLF model was calibrated based on the simulated flows from the Hyco River HSPF model for the period from

January 2005 to December 2012. The Hyco River HSPF model was developed to support the development of bacteria TMDLs for the Hyco River watershed, which includes the Coleman Creek watershed. The calibration involved adjusting the model parameters to obtain an acceptable match between GWLF monthly simulated streamflow and the "observed" monthly streamflow (i.e., HSFP simulated data). Other hydrologic components were calculated including baseflow, seasonal streamflow and total annual streamflow.

Figure 5.1 and Table 5.5 show the comparison of the simulated and "observed" monthly flows. A visual inspection of the results indicates that the GWLF model was able to adequately predict the "observed" values. The percent error in total flow volume is less than 0.5 percent and the seasonal flow volumes (November – April and May – October) are within five percent. In addition, the Nash-Sutcliffe Efficiency (N-S) and the coefficient of determination (R^2) were calculated to be 0.83 and 0.87, respectively which statistically supports that the model was able to predict the "observed" values well.

It should be noted that the statistic R^2 is an indication of the variability in the observed data that is explained by the model. A value of 0.75 for R^2 with intercept close to zero and gradient closer to one indicates a well-calibrated model. On the other hand, N-S values range between 1 and −∞. The closer N-S is to 1 (exact match), the better the model fit. An N-S value that is lower than zero indicates that the mean value of the observed time series is a better predictor than the model. A value of 0.4 or higher for N-S indicates a well-calibrated model.

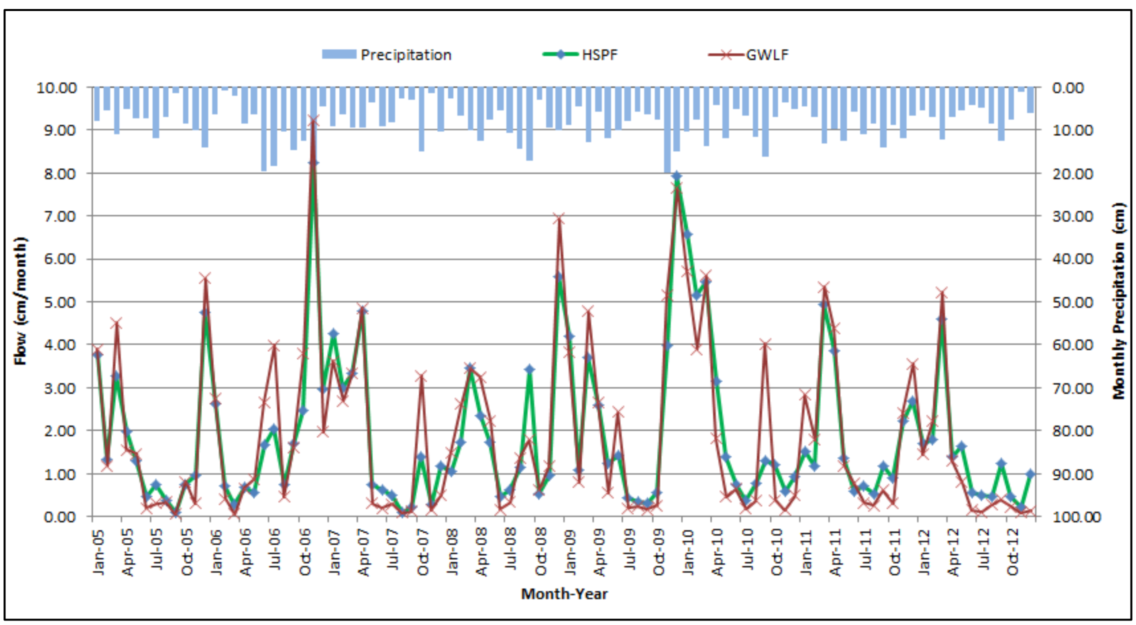

Figure 5.1. Monthly Simulated vs. Observed Flows.

Table 5.5. Average Monthly Simulated vs. Observed Flows.

Month	HSPF Flow (cm)	GWLF Flow (cm)
January	3.21	3.19
February	1.99	1.95
March	3.64	4.04
April	2.60	2.56
May	1.24	0.98
June	0.82	0.91
July	0.75	0.72
August	0.56	0.43
September	1.19	1.10
October	1.03	1.22
November	2.18	2.33
December	3.38	3.35
Note: Percent Error in Total Flow Volume = 0.31 Percent Error in Seasonal Flow Volume: October to March = 3.7 percent April to September = 5.0 percent		

5.4 Sediment Load Estimates

Water quality calibration of the GWLF model was not performed because of limited number of TSS observed data. The quality of the prediction of the model of the sediment loading is therefore highly dependent on the quality of the values selected for model parameters related to sediment accumulation in the different land use types, and amount of erosion from the stream channel.

Table 5.6 shows the estimated annual loads by land use type and from streambank/channel erosion during the simulation period from January 2000 to December 2012 for the Coleman Creek watershed. The annual total sediment load fluctuated from as low as 147 metric tons to more than seven times this value (i.e., as high as 1,077 metric tons). These values when converted to average sediment concentrations result in values as high as 210 mg/L and an average of about 38 mg/L. Observed TSS concentrations within the Hyco River watershed show values as high as 131 mg/L and average value of about 11 mg/L.

Table 5.6. Estimated Annual Sediment Loads by Sources (metric tons).

Year	Total Sediment	Streambank Sediment	Forest	Harvested Forest	Pasture	Riparian Pasture	Crop	Developed	Barren	Hay
2000	555.9	99.5	48.6	18.0	290.3	53.2	6.8	23.4	6.7	9.4
2001	927.6	84.0	72.3	32.7	549.2	100.7	13.8	44.4	13.3	17.3
2002	1761.7	120.7	191.7	62.2	1039.9	190.6	21.5	80.0	20.5	34.5

Year	Total Sediment	Streambank Sediment	Forest	Harvested Forest	Pasture	Riparian Pasture	Crop	Developed	Barren	Hay
2003	3694.9	196.2	421.1	135.0	2207.4	404.6	45.9	168.9	42.6	73.3
2004	522.3	112.1	39.5	15.4	265.5	48.7	6.1	21.0	5.9	8.1
2005	1766.3	90.9	131.6	66.8	1105.1	202.6	25.5	84.4	25.0	34.5
2006	837.0	115.1	84.3	27.3	454.2	83.3	10.6	37.0	10.0	15.1
2007	1443.3	87.2	140.2	53.5	867.2	159.0	19.8	68.6	19.1	28.8
2008	1911.1	111.6	191.5	70.9	1155.4	211.8	23.0	88.3	21.6	37.1
2009	1269.2	112.8	125.9	43.7	741.6	135.9	15.2	57.0	14.3	22.9
2010	1608.6	100.5	137.4	51.4	990.0	181.5	21.6	75.8	20.5	29.9
2011	804.2	106.1	47.6	21.9	469.9	86.2	10.4	37.8	9.9	14.3
2012	779.5	65.5	43.8	20.8	482.9	88.5	11.4	42.2	11.6	12.8
Annual Average	1375.5	107.9	128.9	47.7	816.8	149.7	17.8	63.8	17.0	26.0
Percent	100%	8%	10%	3%	59%	11%	1%	5%	1%	2%

Figure 5.2 shows the relative source distribution based on the annual average sediment load. It shows that 59 percent of the sediment loads is from pasture, 11 percent from riparian pasture, 8 percent from streambank/channel erosion, and 13 percent from forest and harvested forest combined.

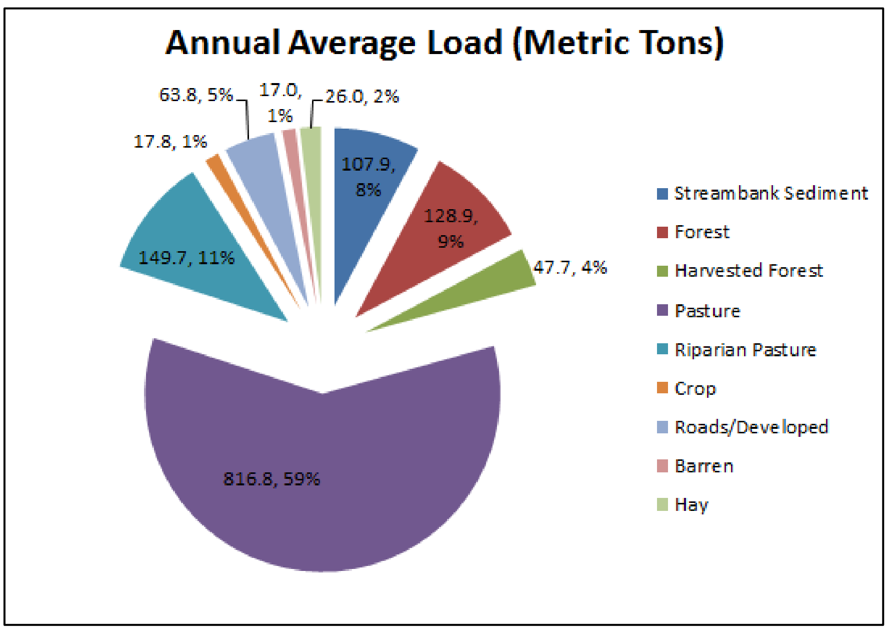

Figure 5.2. Relative Source Distribution of Sediment Load.

5.5 Reference Watershed Sediment Load Estimates

The hydrologically calibrated model for Coleman Creek was applied in Winn Creek to predict the sediment load from the Winn Creek watershed, which is the reference watershed selected for the Coleman Creek watershed. As an approach adopted in previous EPA-approved sediment TMDLs in Virginia, a hydrologically calibrated model is considered adequate to establish the TMDL endpoint and estimate the required sediment load reductions in an impaired watershed relative to the TMDL endpoint without performing a water quality calibration.

Based on NASS land use data from 2012, Table 5.7 shows the land use distribution in the Winn Creek watershed. Similar to the Coleman Creek watershed, harvested forest is assumed three percent of total forest, and riparian pasture is pasture adjacent to and within 100 feet of perennial streams.

Table 5.7 Land Use Distribution in the Winn Creek Watershed.

Landuse	Area (acres)	Percent
Forest	4,716.3	59.87
Pasture	1,737.3	22.05
Hay	739.4	9.39
Urban Green Space	324.6	4.12
Harvested forest	145.9	1.85
Crop	107.6	1.37
Wetland	50.2	0.64
Low Intensity Developed	34.5	0.44
Water	15.3	0.19
Riparian Pasture	5.8	0.07
Medium Intensity Developed	1.1	0.01
High Intensity Developed	0	0
Barren	0	0
Total	7,877.9	100.0

Table 5.8 shows the model parameters that primarily represent the runoff and soil erosion and transport in the watershed. The values of these parameters were estimated using the same approach that was adopted for Coleman Creek, which was based on vegetative cover, soil characteristics, slopes, rainfall intensity, and land management practices. For harvested forest and pasture, the USLE C factor was adjusted for pasture and forest to reflect the difference in land management practices. In consultation with the Technical Advisory Committee (TAC), pasture in the Coleman Creek watershed was assumed to be composed of 10 percent pasture in good condition, 70 percent in fair condition, and 20 percent in overgrazed condition. In the Winn Creek watershed, it was assumed that, on average, pasture is in fair condition.

For forest, it is assumed that the USLE C factor for forest (including harvested forest) in the Coleman Creek watershed is two times higher than that of the Winn Creek watershed to account for significantly higher road density and the number of stream-road crossings in Coleman Creek. This means that, when all other factors are equal (i.e., slopes, soil characteristics and rainfall intensity), the sediment load contribution per unit area of forest in

Coleman Creek is twice that of the Winn Creek watershed. As demonstrated in many studies, roads serve as faster conduits of sediment delivery in forested lands. Using road data from the Virginia Geographic Information Network, the road density and number of stream-road crossings in forested areas in the Coleman Creek are estimated to be, respectively, about 1.5 and 5 times higher than for the Winn Creek watershed.

Table 5.8. Model Parameters by Land Use for the Winn Creek Watershed.

Landuse	CN	K	S	L	LS	C	P	KLSCP
UGR	71.5	0.28	4.36	71.57	3.48	0.027	1.00	0.02651
Developed (Low)	69.1	0.28	3.57	76.50	2.87	0.020	1.00	0.01608
Developed (Medium)	73.8	0.28	3.15	79.29	2.25	0.020	1.00	0.01262
Developed (High)	Area = 0							
Barren	Area = 0							
Forest	58.7	0.29	7.37	55.38	6.75	0.002	1.00	0.00290
Harvested forest	64.6	0.29	7.37	55.38	6.75	0.015	1.00	0.02899
Pasture	71.6	0.29	5.96	62.44	5.38	0.040	1.00	0.06208
Riparian Pasture	81.9	0.29	5.65	64.10	5.09	0.480	1.00	0.70480
Hay	71.3	0.29	5.18	66.73	4.65	0.010	1.00	0.01348
Crop	80.5	0.30	5.05	67.45	4.54	0.049	1.00	0.06737
Wetland	65.8	0.28	5.06	67.39	4.55	0.002	1.00	0.00191

Table 5.9 shows the model parameters used for estimating channel and streambank erosion in Winn Creek. The parameter values were estimated following the same methodology adopted for Coleman Creek.

Table 5.9. Model Parameter Values for Estimating Channel and Streambank Erosion for Winn Creek Watershed.

Parameter	Value
Total Stream Length	49,994 ft (15,242 m)
Mean Channel Depth	2.26 ft (0.69 m)
Area-Weighted Runoff CN	57.8
Area-Weighted Soil Erodibility	0.287
Area-Weighted Slope	6.67 %
Percent Developed Land	4.57
Number of Livestock	401

Table 5.10 shows a summary of annual average sediment loads from the Winn Creek watershed compared to those from the Coleman Creek watershed. The estimated loads from the Winn Creek watershed were adjusted to account for the size difference between the two watersheds. As noted earlier, the estimated total sediment load from the Winn Creek watershed is used as the TMDL endpoint. Table 5.10 shows that the existing average annual load from the Coleman Creek watershed is higher than the TMDL endpoint. The sediment load from Coleman Creek watershed will have to be reduced to a level that takes into account the future growth WLA and MOS.

Table 5.10. Estimated Annual Average Sediment Loads from Coleman Creek and Winn Creek Watersheds.

Land Use/Source Categories	Sediment Loads (metric tons/yr)	
	Coleman Creek	Winn Creek*
Forest	128.9	68.4
Harvested Forest	47.7	23.3
Pasture	816.6	745.2
Riparian Pasture	149.7	28.5
Hay	26.0	68.9
Crop	17.8	61.1
Developed	63.8	62.7
Transitional (Barren)	17.0	0.0
Channel Erosion	107.9	56.0
Total	1,375.5	1,114.1
*Note – Area adjusted reference watershed.		

6.0 TMDLs AND ALLOCATIONS

The objective of a TMDL is to allocate allowable loads among different pollutant sources so that appropriate actions can be taken to achieve water quality standards (USEPA, 1991). Sediment was identified as the "most probable stressor" causing the benthic impairment of Coleman Creek based on the stressor analysis presented in Chapter 3. Therefore, sediment was used as the basis for development of the TMDL. Using the reference watershed approach, the sediment TMDL endpoint for Coleman Creek was set equal to the area-adjusted estimated load for the Winn Creek watershed, the selected reference watershed.

6.1 TMDL Components

The sediment TMDL for Coleman Creek watershed was based on the following equation:

TMDL = WLA + LA + MOS

Where:
TMDL = Total Maximum Daily Load for Coleman Creek
WLA = sum of the wasteload (permitted) allocations (point source contributions and future growth)
LA = sum of load allocations (non-point source contributions); and
MOS = margin of safety

As noted earlier, the TMDL is set to 1,114.1 metric tons/year which is equal to the area-adjusted estimated load for the selected reference watershed.

6.2 Margin of Safety

The Margin of Safety (MOS) accounts for model and data uncertainties. An explicit 10 percent MOS was used, which is the number that has been used for previous EPA-approved sediment TMDLs for benthic-impaired watersheds in Virginia using the reference watershed approach and the GWLF model. This assumption corresponds to a value of 111.4 metric tons/year of sediment load for MOS.

6.3 Waste Load Allocation

Sediment loads in Coleman Creek can be attributed almost exclusively to nonpoint sources. There are no permitted wastewater facilities or active land disturbing (construction stormwater) activities in the Coleman Creek watershed. The watershed is also primarily rural and is not expected to experience any significant development in the future. In fact, Halifax County population declined based on latest Census survey. However, as per VADEQ guidance, Future Growth WLA is set to two percent of the TMDL to allow future permitted construction and development activities beyond what is currently observed in the watershed. This assumption corresponds to a value of 22.3 metric tons/year of sediment load allocated for future growth.

6.4 Load Allocation

The load allocation for nonpoint sources was calculated as the difference between the TMDL, and the sum of WLA and MOS. As shown in Table 6.1, the LA is equal to 980.5 metric tons/year.

Table 6.1. TMDL Expression for the Coleman Creek Watershed (metric tons/year).

TMDL (metric tons/year)	WLA (metric tons/year)	LA (metric tons/year)	MOS (metric tons/year)
1114.1	22.3* *Future Growth WLA	980.5	111.4

6.5 Allocation Scenarios

Table 6.2 shows that the percent reduction required in nonpoint sources to meet the LA as per the TMDL is 28.7 percent, which is equivalent to 395.1 metric tons/year. In order to meet the required overall load reduction, the nonpoint source loads contributed by the different source categories should be reduced. Table 6.3 shows three alternative allocation scenarios that will meet the overall load reduction. Each allocation scenario recommends a target load reduction for each source category. Scenario 1 assumes an equal percent of target load reduction for all source categories except forest. With harvested forest as a separate source category, no target reductions are assigned for forest for any of the three scenarios. Scenario 2 represents the situation where source categories such as pasture/hay/riparian pasture, harvested forest, and channel erosion that have significantly higher load contribution per unit area are targeted for reduction.

Scenario 3 represents the scenario where the overall required load reduction is achieved through targeted reductions from all nonpoint sources in the watershed (i.e., not including channel erosion). The final allocation scenario for implementation will be selected during the TMDL implementation planning.

Table 6.2. Required Load Reduction and Percent Reduction for Coleman Creek Watershed to Meet TMDL.

Existing NPS loads (metric tons/year)	1,375.5
Load Allocation (LA) (metric tons/year)	980.5
Load Reduction Required (metric tons/year)	395.1
Percent Load Reduction Required	28.7

Table 6.3. TMDL Allocation Scenarios for the Coleman Creek Watershed.

Land Use	Target Load Reduction (Percent)		
	Scenario 1	Scenario 2	Scenario 3
Forest	0	0	0
Harvested Forest	32	34	36
Pasture/Hay/Riparian Pasture	32	34	36
Crop	32	0	20
Developed (including barren land use)	32	0	20
Channel Erosion	32	34	0

6.6 Consideration of Critical Conditions

The GWLF model is a continuous simulation model that uses daily time steps for weather data and water balance calculations. The period of rainfall selected for modeling was from January 2000 to December 2012. This period is considered representative of typical weather conditions in Coleman Creek watershed, and included "dry," "normal," and "wet" years. The model, therefore, incorporated the variable inputs needed to represent critical conditions during low flow – generally associated with point source loads – and critical conditions during high flow – generally associated with nonpoint source loads. For Coleman Creek, nonpoint sources and in-stream erosion practically account for all of the total sediment loads to the stream. Therefore, the most important critical conditions are associated with high flows when sediments from nonpoint sources are carried into the stream with wet weather runoff.

6.7 Consideration of Seasonal Variability

Seasonal variations were explicitly incorporated in the approach through the use of the GWLF model, which is a continuous simulation model. The Coleman Creek GWLF model used daily time steps for weather data and water balance calculations and monthly values for evapotranspiration cover coefficients, daylight hours/day, and rainfall erosivity coefficients.

6.8 Expression of Maximum Daily Loads

Current regulation requires that that TMDL studies submitted since 2007 include a maximum "daily" load (MDL), in addition to the average annual loads shown in Table 6.1. The Coleman Creek sediment TMDL was expressed as a daily load following USEPA (2007) guidance that involves the calculation of a multiplier (M) for adjusting the long-term daily average (LTA) load.

The multiplier (M) is calculated by evaluating the variability and distribution of the monthly simulated loads in Coleman Creek.

$$M = Z_{95}\,\sigma \quad - 0.5\sigma^2$$

Where

Z_{95} = 95th percentile of a standard normal distribution

$\sigma^2 = \ln(CV^2 + 1)$

CV = coefficient of variation

The MDL is calculated using the following equation:

$$MDL = LTA \times M$$

Where

MDL = maximum daily load (metric tons/day)

LTA = long-term daily average (metric tons/day) which is the average annual load divided by 365

Based on the monthly simulated values from 2000 to 2012, the CV and M were calculated to be 2.04 and 3.62, respectively. With LTA equal to 3.05 metric tons/day, the daily load expression of the Coleman Creek sediment TMDL were calculated as shown in Table 6.4.

Table 6.4. TMDL Expression for Coleman Creek Watershed (metric tons/day).

TMDL (metric tons/day)	WLA (metric tons/day)	LA (metric tons/day)	MOS (metric tons/day)
11.05	0.22* *Future Growth WLA	9.73	1.10

7.0 TMDL IMPLEMENTATION

The goal of the TMDL program is to establish a three-step path that will lead to attainment of water quality standards. The first step is to develop TMDLs that will result in meeting water quality standards. This report represents the culmination of that effort for the benthic impairment in Coleman Creek. The second step is to develop a TMDL Implementation Plan. The final step is to implement the TMDL Implementation Plan and to monitor stream water quality to determine if water quality standards are being attained.

Once a TMDL has been approved by the State Water Control Board (SWCB) and the U.S. Environmental Protection Agency (USEPA), measures must be taken to reduce pollutant levels in the stream. These measures, which can include the use of better treatment technology and the installation of BMPs, are implemented in an iterative process that is described along with specific BMPs in the Implementation Plan. The process for developing an Implementation Plan has been described in the "TMDL Implementation Plan Guidance Manual", published in July 2003 and available upon request from the VADEQ and DCR TMDL project staff or at the time of this publication, also found, here:

http://www.deq.virginia.gov/Portals/0/DEQ/Water/TMDL/ImplementationPlans/ipguide.pdf.

With successful completion of Implementation Plans, Virginia begins the process of restoring impaired waters and enhancing the value of this important resource. Additionally, development of an approved Implementation Plan will improve a locality's chances for obtaining financial and technical assistance during implementation.

Watershed stakeholders will have opportunity to participate in the development of the TMDL Implementation Plan, which is the next step in the TMDL process. Specific goals for BMP implementation will be established as part of the Implementation Plan development. VADCR and VADEQ will work closely with watershed stakeholders, interested state agencies such as the Department of Forestry, and support groups to develop an acceptable Implementation Plan that will result in improving the benthic community and meeting the general water quality standard.

7.1. Link to ongoing Restoration Efforts

Coleman Creek is also listed as not meeting its recreational designated use due to bacteria. A bacteria TMDL for Coleman Creek is being developed in parallel with this TMDL study. Implementation of BMPs to address the benthic impairments in Coleman Creek will be coordinated with BMPs required to meet bacteria water quality standards.

7.2. Reasonable Assurance for Implementation

7.2.1 TMDL Monitoring

VADEQ will monitor benthic macroinvertebrates and habitat in accordance with its biological monitoring program at Station 4ACLB004.14 along Coleman Creek. VADEQ will continue to use data from these monitoring stations to evaluate improvements in the benthic community and the effectiveness of TMDL implementation in attainment of the general water quality standard.

7.2.2 Regulatory Framework

7.2.2.1 Federal Regulations

While section 303(d) of the Clean Water Act and current USEPA regulations do not require the development of TMDL implementation plans as part of the TMDL process, they do require reasonable assurance that the load and wasteload allocations can and will be implemented. Federal regulations also require that all new or revised National Pollutant Discharge Elimination System (NPDES) permits must be consistent with the assumptions and requirements of any applicable TMDL WLA (40 CFR §122.44 (d)(1)(vii)(B)).

7.2.2.2 State Regulations

Additionally, Virginia's 1997 Water Quality Monitoring, Information and Restoration Act (WQMIRA) directs the State Water Control Board to "develop and implement a plan to achieve fully supporting status for impaired waters" (Section 62.1-44.19.7). WQMIRA also establishes that the implementation plan shall include the date of expected achievement of water quality objectives, measurable goals, corrective actions necessary and the associated costs, benefits and environmental impacts of addressing the impairments. USEPA outlines the minimum elements of an approvable implementation plan in its 1999 "Guidance for Water Quality-Based Decisions: The TMDL Process." The listed elements include implementation actions/management measures, timelines, legal or regulatory controls, time required to attain water quality standards, monitoring plans and milestones for attaining water quality standards.

For the implementation of the WLA component of each TMDL, the Commonwealth utilizes the Virginia NPDES program, which typically includes consideration of the WQMIRA requirements during the permitting process. Requirements of the permit process should not be duplicated in the TMDL process and implementation plan development, especially those implemented through water quality-based effluent limitations. However, those requirements that are considered BMPs may be enhanced by inclusion in the TMDL IP, and their connection to the identified impairment. New permitted point source discharges will be allowed under the waste load allocation provided they implement applicable VPDES requirements.

7.2.3 Implementation Funding Sources

Implementation funding sources will be determined during the implementation planning process by the local watershed stakeholder planning group with assistance from VADEQ and VADCR. Potential sources of funding include Section 319 funding for Virginia's Nonpoint Source Management Program, the U.S. Department of Agriculture's Conservation Reserve Enhancement and Environmental Quality Incentive Programs, the Virginia State Revolving Loan Program, and the Virginia Water Quality Improvement Fund, although other sources are also available for specific projects and regions of the state. The TMDL Implementation Plan Guidance Manual contains additional information on funding sources, as well as government agencies that might support implementation efforts and suggestions for integrating TMDL implementation with other watershed planning efforts.

7.2.4 Reasonable Assurance Summary

Watershed stakeholders will have opportunities to provide input and to participate in the development of the implementation plan, which will also be supported by regional and local offices of VADEQ, VADCR, and other cooperating agencies.

Once developed, VADEQ intends to incorporate the TMDL implementation plan into the appropriate Water Quality Management Plan (WQMP), in accordance with the Clean Water Act's Section 303(e). In response to a Memorandum of Understanding (MOU) between USEPA and VADEQ, VADEQ also submitted a draft Continuous Planning Process to USEPA in which VADEQ commits to regularly updating the WQMPs. Thus, the WQMPs will be, among other things, the repository for all TMDLs and TMDL implementation plans developed within a river basin.

Taken together, the follow-up monitoring, WQMIRA, public participation, the Continuing Planning Process, and the reductions called for in the concurrent bacteria TMDL on Coleman Creek comprise a reasonable assurance that the Coleman Creek sediment TMDL will be implemented and water quality will be restored.

8.0 PUBLIC PARTICIPATION

The sediment TMDL for Coleman Creek was developed with the participation and input of the public at various stages of the process.

A conference call with the Technical Advisory Committee was held on December 12, 2013, to introduce to the agency stakeholders the Coleman Creek benthic TMDL along with bacteria TMDLs in Hyco River, Aarons Creek, Little Buffalo Creek, and Beech Creek watersheds. During the call, the TMDL projects were introduced, and the proposed modeling approach and the data available to support the analysis were discussed with the attendees. The attendees included representatives from VADEQ, Halifax County, Natural Resources Conservation Service in Halifax, and the Department of Health.

A number of follow-up consultations via the phone with individual members of the Technical Advisory Committee were conducted to discuss available data and solicit any anecdotal information about the watersheds.

The first Public Meeting was held at the Midway Volunteer Fire Department in Virgilina, Virginia, on January 9, 2014. The scope of the meeting included both the bacteria and benthic impairments in the Hyco River, Aarons Creek, Little Buffalo Creek, and Beech Creek. During the meeting, presentations were made to introduce the TMDL process and the local stream impairments including Coleman Creek which is listed for both benthic and bacteria impairments. The proposed modeling approach and data available were also presented. Comments were solicited from the participants during the meeting. A news article on the local Gazette-Virginian paper was published on May 11, 2014, by the local journalist who attended the first public meeting.

A second and final public meeting will be held on [TBD] to present the draft TMDL report for bacteria and benthic impairments in the aforementioned watersheds. A 30-day public comment period will follow the second public meeting. Comments received during the public meeting and the 30-day period will be evaluated and addressed.

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APPENDIX A. COLEMAN CREEK – POTENTIAL STRESSOR CHECKLIST

Ammonia

- High ammonia values (variable pH and temperature dependent WQS)?......................_N_

pH

- Extreme DEQ pH values – (normal range: 6.0 – 9.0)?..._N_
- Extreme VAHWQP county-level pH values in well water or tap samples?
    - Halifax County, 51% < 6.5………………………………………………………………………………_Y_

Temperature

- High summer water temperatures values (Class III waters WQS – 32°C)?.................. _N_
- Low riparian vegetation score in habitat evaluation?.._N_

Metals (dissolved, sediment, cumulative)

- DEQ channel bottom sediment samples with metals concentration above consensus-based PEC?..._N_
- DEQ water column samples with metals concentrations above aquatic life or human health criteria)?..._N_
- Extreme concentrations in VAHWQP drinking water samples?...................................._Y_

Toxic Organic Compounds

Benthic data

- Low total numbers of organisms?..._Y_

Stream Sediment Data

- Exceedances of consensus-based Probable Effects Concentrations by

sediment samples?..._N_

DEQ Permitted Point Source Dischargers

- Four domestic permits……………………………………………………………………………………._N
- Known of suspected historical users of toxic substances in the watershed……………..._N

Ancillary data

- Problems reported in VAHWQP drinking water analyses?..._N
- EPA laboratory toxicity tests with *Ceriodaphnia* and fathead minnow (or other sensitive species)?.._ND_
- Field Observations
    - Absence of fish?.._ND_

<u>Nutrients (DO)</u>

Benthic Data

- Dominance of *Chironomidae*, *Hydropsychidae*, or *Simuliidae* (may indicate elevated nutrients)?..._Y_
- Dominance of algae-eating fish species (e.g., central stonerollers)?.........................._ND_
- High degree of dominance by one or two species?..._Y_

Habitat Data

- Low riparian vegetation habitat scores (may allow increased nutrient inputs from overland flow)?..._N_

Chemical/Physical Data

- Average N and P ambient monitoring data – eutrophic sufficiency levels: dissolved N > 0.3 mg/L; dissolved P > 0.01 mg/L ?..._Y_
- Limiting nutrient – if N:P > 10, P is limiting; if N:P < 4, N is limiting?............................_Y_
- High N and P in DEQ wastewater facility sampling inspection reports or monthly discharge reports?.._N?_
- Exceedance of DEQ's observed effects TP threshold (0.2 mg/L)?..............................._N_

Ancillary Data

- VAHWQP county-wide drinking water samples > 10 mg/L nitrate-N?
    - Halifax County 0% > 10 mg/L.._N_

Field Observations

- Observed growth/slime/algae in streams?.._N_

<u>Organic Matter</u>

Benthic Data

- Moderate to high values of MFBI metric (>~5.00) may indicate organic pollution?....._Y_

- Dominance of Hydropsychidae organisms (indicates availability of suspended fine particulate organic matter)?.._N_
- Presence of Asellidae, Oligochaetae, or Tubificidae organisms?..................................._Y_
- A low value (<~0.5) for the SC/CF ratio metric or a high number of filterer/collectors

(FC) that indicates availability of suspended fine particulate organic matter?........................_Y_

Chemical/Physical Data

- High TOC values (gw criteria = 10 mg/L)?.._Y_
- High volatile solids and high BOD_5 values (combination indicative of organics)?.........._N_
- High BOD_5 values (effluent standard 6-8 mg/L)?..._N_
- High COD values (effluent standard 10 mg/L)?.._ND_
- Low DO values (Class III Waters WQS 5.0 mg/L)?.._Y_
- High levels of TKN relative to nitrate-N indicating larger percent

organic N?..._Y_

Ancillary Data

- Large diurnal DO fluctuations (> 1/3rd percent saturation)?......................................_ND_

Observations

- Extensive livestock access to streams or observed livestock manure in creeks?........_ND_

Streambed Sedimentation

Benthic Data

- Low percent Haptobenthos (implies lack of clean, coarse substrate)?......................._N

Habitat Data

- Habitat Evaluation Scores (0=worst, 20=best). Bedload sediment may be indicated by low scores of bank stability, riparian vegetation, and/or sediment deposition?..........._Y_

Physical/Chemical Data

- High DEQ ambient non-filterable residue?..._N_
- High TSS concentrations or turbidity during runoff events?......................................_ND_
- High non-filterable residue (TSS) from point source dischargers?............................._ND_

Ancillary Data

- Low Riffle Stability Index (indicating anthropogenic influences)?

- Low Relative Bed Stability Index (LRBS)?.._NA_
- Presence of silt-intolerant fish species?.._ND_
- Percent imperviousness?...N_
- Evidence of channel straightening?...N_
- Incised stream banks?...ND_
- Poor riparian vegetation habitat metric scores?...N_
- Number of road crossings per stream mile?...N_
- Number of total habitat scores < 120?...Y_

Field Observations

- Observed stream embeddedness?...NA_
- Observed construction sites?..ND_
- Observed forest harvesting sites?...ND_
- Observed clean-tillage farming?..ND_
- Observed livestock access to streams and trampled streambanks? ...._ND_

Ionic Strength

- High DEQ conductivity values

(Reference screening values > 500 umhos/cm)?...N_

ND = no data

NA = not applicable

APPENDIX B. STRESSOR ANALYSIS EVIDENCE SHEET FOR COLEMAN CREEK

Ammonia:

- Supportive:
- Non-supportive: Essentially one year of data but all concentrations were low.

pH

- Supportive: More than 50 percent of the VAHWQP samples in 2013 were below the minimum pH threshold for that program.
- Non-supportive: One in-stream pH measurement out of 57 total measurements from all the Coleman Creek watershed monitoring sites was below the minimum or above the maximum standards.

Temperature

- Supportive: The scores for riparian vegetative zone width were marginal in May 2012 and poor in November 2012.
- Non-supportive: No measurements of temperature above the maximum Class III water quality standard (32°C) have been recorded in the Coleman Creek watershed. Scores for bank vegetative protection in 2006 and 2012 indicated good bank protection and likely sources of shade.

Metals

- Supportive:
- Non-supportive: None of the water column or sediment analytes were above the benchmark criteria for levels that indicate possible effects on the invertebrate community.

Toxic Organic Compounds

- Supportive:
- Non-supportive: None of the sediment analytes were above the benchmark criteria for levels that indicate probable or threshold effects on the invertebrate community.

Nutrients

- Supportive: Three out of 36 TP samples were in the sub-optimal range, though none exceeded the “observed effects” threshold of 0.2 mg/L. Generally high levels of organic N. Dominance of *Chironomidae.* N:P ratio greater than 10 so P is limiting.
- Non-supportive: Acceptable riparian vegetation habitat metric scores.

Organic Matter

- Supportive: Benthic data suggest organic enrichment (high filterer/collector numbers, Asellidae, MFBI). Physical/chemical data also show high organic carbon, low dissolved oxygen, and high TKN (especially organic N).

- Non-supportive: Few Hydropsychidae organisms and no DO exceedance at biological monitoring station 4ACLB001.90 in 2006.

Streambed Sedimentation

- Supportive: Bedload sediment may be indicated by low scores of bank stability, riparian vegetation, and/or sediment deposition. Total habitat scores less than 120 in 2012.
- Non-supportive: Moderate percent Haptobenthos, positive LRBS, little indication of development.

Ionic Strength

- Supportive:
- Non-supportive: Moderately low conductivity values.